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VEHICULAR VARIABLE-PARAMETER METRRA SYSTEM

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IIT Research Institute

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13. ABSTRACT

This combined final report/instruction manual describes the variable parameter METRRA System designed and developed by IIT Research Institute, Chicago, Illinois, for the U.S. Army Mobility Equipment Research and Development Center, Fort Belvoir, Virginia.

This system has been set up at Aberdeen Proving Ground, Maryland, preparatory to entering the data-taking phase.

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FOREWORD

This combined Final Report/Instruction Manual, in conjunction with the two-volume Instruction Manual provided by Acrodyne Industries, Inc. for the METRRA transmitter, constitutes the "Final Report" of the METRRA System.

Many people contributed to the successful completion of this program. Particular appreciation is due Messrs. George Roshon, John Zemany and Joseph De Courcelle of Acrodyne for technical consultation and advice given for a long period after acceptance of the transmitter. Carl Whitenton of the Astro Communication Laboratory has performed a similar service for the receiver.

Many people at IIT Research Institute contributed greatly to the system. Mr. Marvin Anderson, Assistant Director of Research, provided administrative guidance. Mr. Marvin Frazier of the EMC/EMP Section provided overall system design guidance. Dr. John Dabkowski performed the system analyses which culminated in specifications for transmitting and receiving filters as well as specifications for the crystal-controlled frequency sources used in the transmitter and receiver. Messrs. William Davidson and Vincent Formanek were responsible for the design and construction of the boxcar unit. Messrs. Scott Cameron, Ron Schwab and Charles Radgowski were responsible for all aspects of the digital data system. Mr. Emil Emerle contributed the discussion of receiver theory and operation and also the section on system calibration. Mr. Robert Heidelmeier performed both system and detailed mechanical design for the system. Mr. Joseph Dombrowski performed liaison work culminating in selection of Aberdeen Proving Ground as the system test site. Mr. Raymond Elsner provided the system coordination and headed the field test

crew, which consisted of Messrs. Emil Emerle, Joseph Freitas, Benjamin Nelson, Sam Tumarkin, William Lancaster, and Ronald Alleruzzo.

The efforts of MERDC Technical Monitors, Mr. Howard Webb, Sr. and Mr. Peter McConnell, in contributing to the solutions of difficult technical problems is greatly appreciated. Dr. William Saunders of HDL provided special consultation during system checkout. Mr. Donald DiDomenico of Aberdeen Proving Ground performed the vital service of coordinating system requirements with the facilities of APG.

Respectfully submitted,
IIT RESEARCH INSTITUTE

Raymond Elsner

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SUMMARY

This combined Final Report/Instruction Manual describes the Variable Parameter METRRA System designed and developed by IIT Research Institute, Chicago, Illinois, for the U.S. Army Mobility Equipment Research and Development Center, Fort Belvoir, Virginia.

This system has been set up at Aberdeen Proving Ground, Maryland, preparatory to entering the data-taking phase. Test data was collected during the period 30 May 1973 through late November 1973.

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1. INTRODUCTION

1.1 General

This Final Report and Instruction Manual is intended to describe the Variable Parameter METRRA System (hereafter designated as the VP METRRA), depict its performance, and provide operating and maintenance instructions.

Separately-bound instruction manuals for the transmitter, receiver, truck, diesel generator, air conditioning system, data system and many of the purchased assemblies are available at the system test site.

1.2 Definition of METRRA

The acronym, METRRA, refers to "Metal Re-Radiating Radar". A METRRA system differs from conventional radar primarily in that the METRRA utilizes a third-harmonic return from a target while a conventional radar utilizes a return at the fundamental frequency.

A conventional radar can obtain returns from undesired targets such as trees, water, etc. A METRRA radar is not affected by such clutter since it depends on nonlinear junctions, usually the result of fabrication processes, inherent in certain classes of man-made metallic structures. These nonlinear junctions receive transmitted energy and re-radiate harmonics of the transmitted frequency (intermodulation products are generated when more than one transmitter is radiating) which can be received by the METRRA receiving system.

1.3 Purpose of Vehicular Variable Parameter METRRA System

The Vehicular Variable Parameter METRRA system was designed and developed specifically to provide instrumentation capable of measuring the third-harmonic outputs of certain

classes of targets subjected to variations of frequency, field strength, polarization, aspect, target condition and acoustic excitation.

1.4 Condensed System Parameters

1.4.1 Transmitter

Frequencies: 230.0, 307.7, 436.1, 550.9, 737.0 MHz.
Output Power: 100 watts CW, 5 kW peak pulse power.
Pulse Width: Adjustable from 0.1 to 1.0 microseconds.
PRF: Adjustable between 1 kHz and 20 kHz.

1.4.2 Receiver

Type: Coherent
Receiving Frequencies Used: 690.0, 923.1, 1308.3, 1652.7, 2211.0 MHz. These are the third harmonics of the transmitted frequencies.
Receiving Range Available: 150-500 MHz (SH-820P Tuner Head), 500-1000 MHz (SH-821P Tuner Head), 1-2 GHz (SH-822P Tuner Head), 2211 MHz only (Modified SH-823P Tuner Head).
Noise Figures (Receiver Only): 250-500 MHz, 12 dB maximum; 500-1000 MHz, 14 dB maximum; 1-2 GHz, 16 dB maximum; 2211 MHz, 18 dB maximum.

1.4.3 Noise Figure (Receiver Plus Pre-Amplifiers)

6 dB
IF Selectivity: 1 MHz
Dynamic Range: 60 dB

1.5 Condensed Test Parameters

1.5.1 Large Target Tests:

Antenna Height Above Ground: Approximately 55 feet.
Antenna Angle: 25° below horizontal.
Antenna Polarization: Horizontal or vertical.
Transmitted Power Density at Target: 0.87 watts per square meter (for both polarizations).

Target Conditions: Quiescent (power turned off), activated (engine running, target stationary), operating (target moving at constant velocity).

1.5.2 Small Target Tests

Antenna Height Above Ground: 8 feet

Antenna Angle: Parallel to earth's surface.

Antenna Polarization: Horizontal (targets may be tested in two planes).

Transmitted Power Density at Target: $20W/m^2$, $2W/m^2$, $0.2W/m^2$, $0.02W/m^2$.

Nominal Spacing Between Antennas and Target: 19 feet.

1.6 Changes in Concept

Several changes in concept occurred during the course of the contract which greatly affected system performance. The original contract called for a frequency tunable system having two transmitters so that intermodulation products and harmonics could be received. The tunable system was built but later modified in accordance with the contractual test program which specified fixed frequencies (to limit the amount of transmitting and receiving bandpass filters to a practical number) and a need for harmonic test data only. Harmonic test data was required for the following reasons:

1. Present operational METRRA systems use detection of harmonics only.
2. A data base was required for analysis and optimization of such future systems.
3. The amount of data to be collected for the harmonic measurements alone was very large.

Originally, the van instrumentation had no coherency requirements at all and the exact intended data analysis subsystem was not specified. IITRI incorporated the coherent function to aid in determining possible short term correlation of targets. By the time these concept changes were specified, particularly the addition of stringent system coherency requirements which were not specified in the contract for the instrumentation vehicle

but were added to make the van instrumentation compatible with the later-determined data analysis requirements, the instrumentation package was nearing completion. This necessitated field modifications to the system, primarily substitution of crystal-controlled frequency sources in the transmitter to replace the original wide-range, continuously-tunable oscillators and modifying the receiver to incorporate crystal control when receiving 2211.0 MHz (the receiver had sufficient stability at the other four receiving frequencies). The required degree of phase stability could not be obtained without these modifications plus the replacement of unregulated high-voltage power supplies in the transmitter by commercial highly-regulated supplies, replacing the transmitter 6.3 VAC unregulated filament transformers with highly-regulated 6.3 VDC supplies, and incorporating a high degree of van temperature stability which was not required originally.

2. DESCRIPTION

2.1 General

The Vehicular Variable Parameter METRRA system consists of a truck-mounted instrumentation van plus associated transmitting and receiving antennas.

2.2 Vehicle

The VP METRRA vehicle is a conventional gasoline-powered cab truck having a 175-inch wheelbase.

A 15 kW diesel-powered generator is mounted on a platform behind the van body.

Two 25-gallon saddle tanks are mounted on the truck chassis. They contain diesel fuel for the diesel-powered generator.

Twc 18" x 18" x 48" weatherproof tool boxes are mounted under the body, one at each side, for storage purposes.

2.3 Van Body

The specially-fabricated van body is mounted on the truck chassis.

Special fabrication techniques were employed so that modified conventional truck-body construction could be employed.

The body itself is constructed from aluminum structural members and aluminum sheeting. The aluminum sheets have overlapping seams rivetted every 1 1/2 inches. The seams are untreated to permit metal-to-metal contact. No mastic or other sealant was used between the faces. This type construction permits a conventionally-structured body to attain a reasonable amount of shielding effectiveness.

Only one door is used, on the curb side of the body. It is constructed of aluminum and has cast steel hardware with a bar-type internal handle and conventional external

handle. Mating surfaces of the door are fitted with RFI gasketing (finger stock). The floor of the body is constructed of 1/16 inch sheet steel. The floor is connected to the aluminum body walls by overlapping seams rivetted every 1 1/2 inches. Below this steel floor is a 1 1/8 inch oak floor.

The body's interior sides, front, rear and ceiling have 2 inch thicknesses of polyurethane foam insulation. This, in turn, is covered with white-surfaced plywood.

Two 2" x 10" oak planks are bolted to the side walls to provide bases for anchoring shock mounts required by two internal equipment racks.

Figures 1 and 2 show two views of the vehicle with body attached, taken before the internal electronic equipment was installed. Air-conditioning equipment can be seen mounted against the top front of the van body (over the truck cab).

A small optically-transparent window is provided on the left side of the body to permit viewing of target positioning without opening the door. Special RFI-type glass is provided for the window.

2.4 Generator

The diesel generator, shown mounted on the vehicle in Figures 1 and 2, has a rated output of 15 kW continuous at 0.8 power factor. When used intermittently, its output is rated at 20 kW. Output is 120/240 volts, single-phase three-wire, 60 Hz.

This unit was selected to power all equipment associated with the Vehicular Variable-Parameter METRRA System.

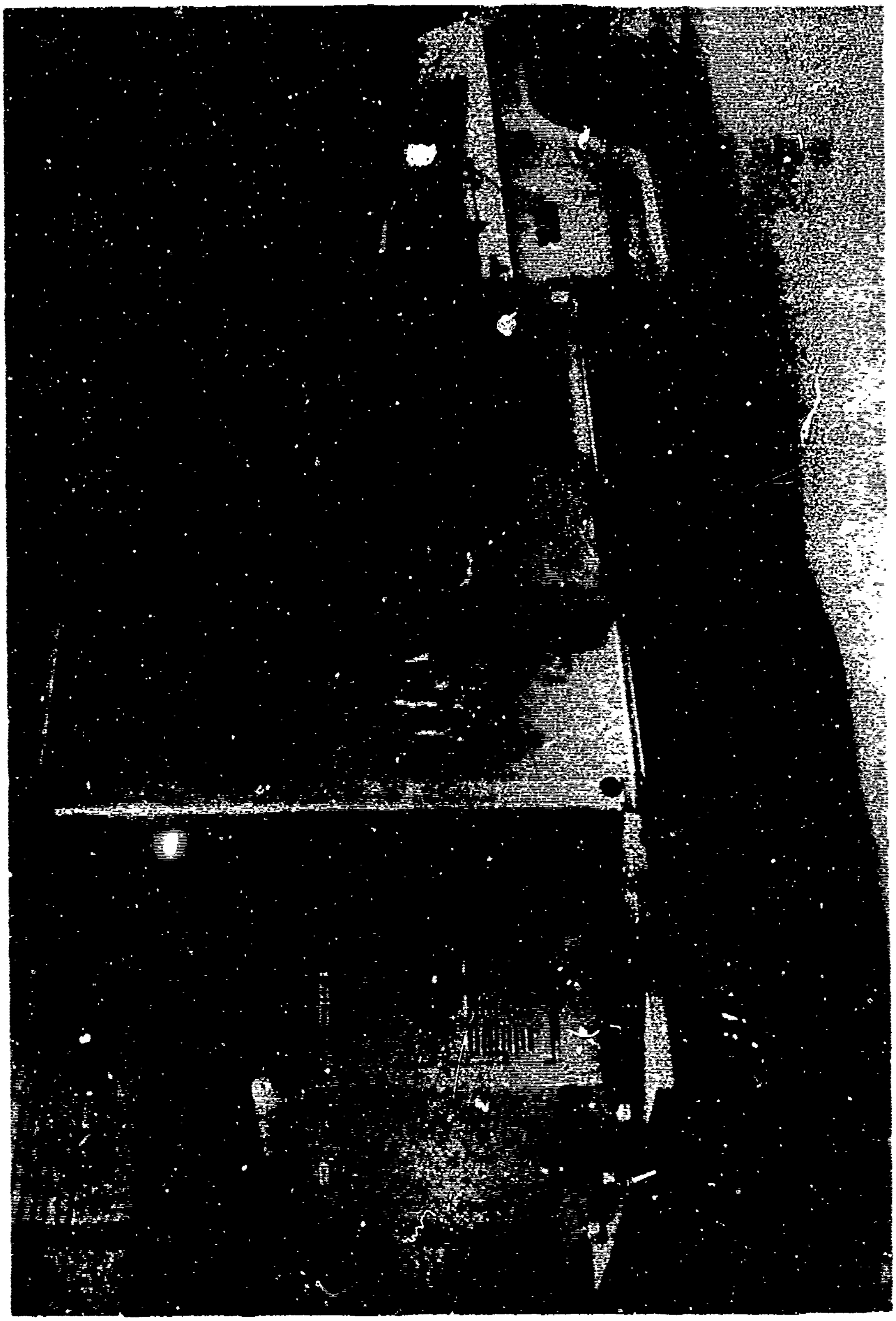

Fig. 1 MOBILE METRRA LABORATORY

Fig. 2 MOBILE METRRA LABORATORY

2.5 Air-Conditioning System

The air-conditioning system is required primarily to provide adequate cooling air for the transmitter.

Physically, the system consists of a condensing unit and a fan coil unit, both mounted above the vehicle cab, and a ceiling duct within the van body used to control and direct cooling air within the van body. Cool air enters the body through an overhead duct and is drawn into the transmitter by means of three blowers located at the bottom of the three transmitter racks. Hot air exits from the tops of these three racks into a close-fitting return ducting system. Ceiling louvers are adjustable and are used to vary the amount of cooling air entering the body. Two 1 kW heaters are mounted at floor level.

In addition, a 10 kW SCR-controlled electric heater is installed in the supply air duct outside the van. An adjustable thermostat mounted on the forward interior wall of the van adjusts the heater output as a function of van interior temperature.

The air-conditioning system is designed to maintain the interior of the van body at 80°F or less. In summer, this temperature will be maintained and inside humidity will be a maximum of 55% when outdoor temperature is a maximum of 95°F dry bulb and 75°F wet bulb. In winter, the internal temperature of 80°F or less will be obtained for outdoor temperatures down to -20°F. The air-conditioning system is rated at 30,000 BTU.

2.6 Electrical Installation

2.6.1 External

Primary power can be supplied by the VP METRRA diesel generators; an external 60 Hz,120/240 VAC single-phase diesel generator; and external 60 Hz, 120 VAC, three-phase

generator; or a commercial power line having characteristics similar to the mentioned external units. Spark-fired motor-generators are not suitable because of potential ignition interference to the VP-METRRA system. A 50-foot, 3 conductor power cable is furnished for connection to external power units.

An external switch box (Figure 3) is located on the outside rear wall of the van. It serves the primary purpose of selecting either the system generator or an external source as the primary power input. This box also contains individual switches for the air conditioner blower, heater and compressor, as well as a switch which provides power to an external AC receptacle located below the switch box. Lighted indicators show the status of the AC power system.

2.6.2 Internal

All primary power lines enter and leave the van body through RFI (Radio-Frequency Interference) filters to prevent line noise from entering the enclosure. Large size units are used where the primary power enters the van body to supply AC power to the internal equipment (Figure 4).

AC line voltage and line frequency meters are located within the van in a box mounted above the power input box.

A main power switch box is located below the power input box (Figure 5). It provides circuit breakers switching to the internal equipment (transmitter, equipment rack, lights, heaters, bench power and AC power to the externally-located preamplifier box).

The heater switch controls the electric floor heaters, one of which is mounted at the front of the enclosure and the other is mounted at the rear.

Figure 3 EXTERNA'. SWITCH BOX

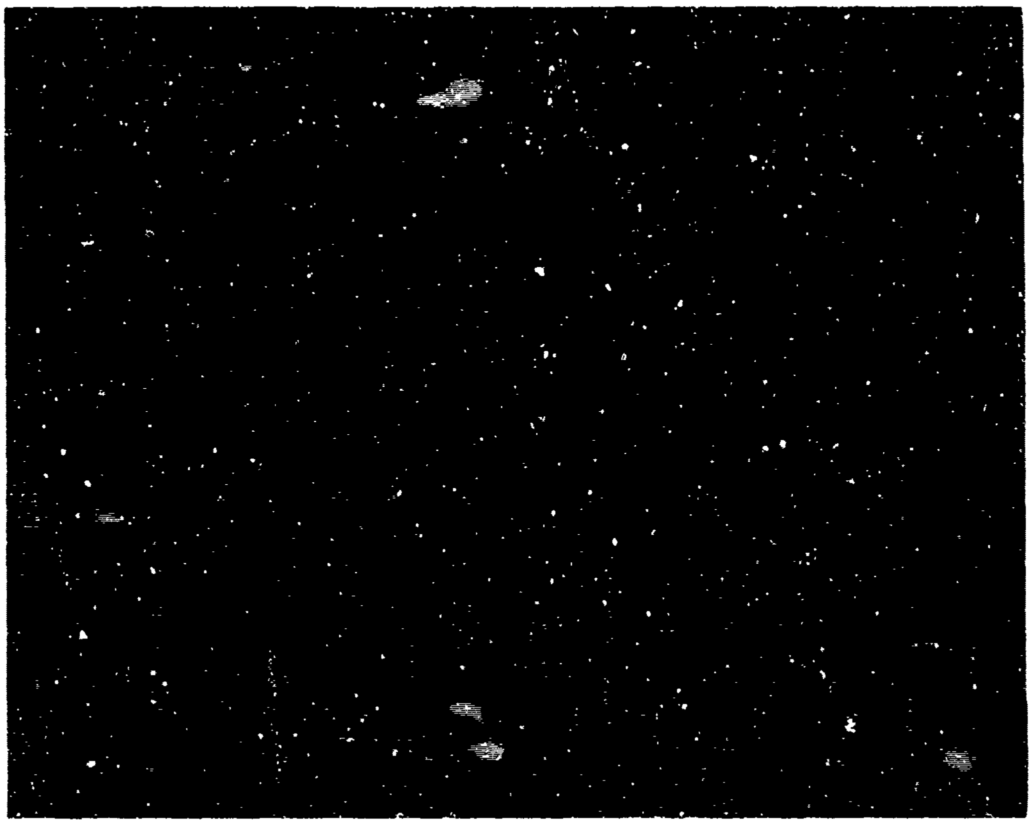

Figure 4 RFI FILTERS

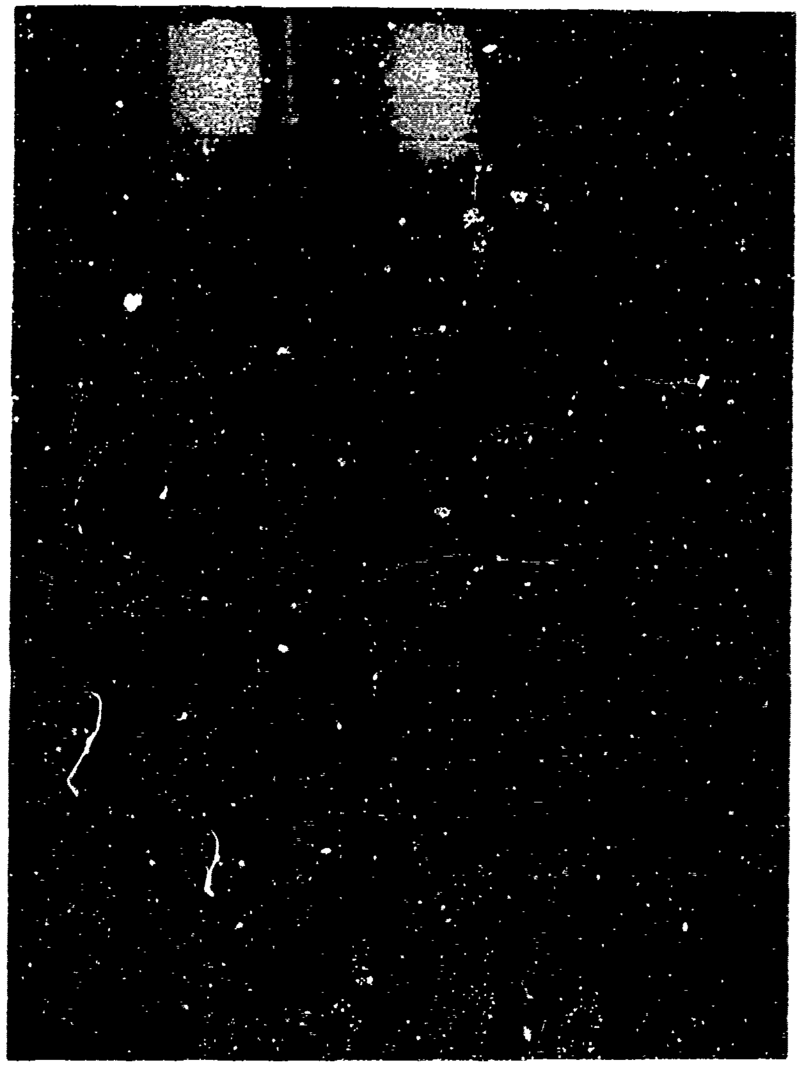

Figure 3 MAIN POWER SWITCH BOX

A central overhead light is battery-powered. A switch mounted next to the van door can turn it on only when AC power is turned off. Adjustable incandescent lights and 120 VAC convenience outlets are placed at the tops of the transmitter and equipment racks.

2.7 Equipment

One three-bay RFI-type rack contains the transmitter. The other three-bay rack has conventional (non RFI-type) construction and contains electronic instrumentation including a tape drive, oscilloscope, frequency counter, four signal generators, data interface unit, tape punch and reader, computer, coherent receiver, receiver boxcar unit, heads for receiver, variable delay line, transmitter remote control panel, AC VTVM, pulse generators, and a spectrum analyzer. Storage drawers are located at the bottom of each bay in the instrumentation rack.

In addition to the two racks, a small workbench and a wall-mounted storage cabinent are provided. The bench contains four drawers for storage purposes. A small fire extinguisher is also located in the van.

2.8 Transmitter

The transmitter is actually two individual transmitters, mounted in the three-bay rack, which use common power supplies. The left bay contains transmitter No. 1, the right bay contains transmitter No. 2 and the center bay contains the common power supplies and control functions.

Transmitter frequencies are 230.0 MHz, 307.7 MHz, 436.1 MHz, 550.9 MHz, and 737.0 MHz.

Nominal power is 100 watts CW per transmitter or 5 kW peak pulse power per transmitter. Pulse width is adjustable between 0.1 and 1.0 microseconds. Pulse recurrence frequency (PRF) is adjustable between 1 kHz and 20 kHz.

The two transmitters can radiate simultaneously but on different frequencies when "intermodulation" testing is required.

2.9 Receiver

The coherent receiver (Figure 6) covers the frequency range from 250 MHz to 2 GHz, using three continuously-tuned plug-in heads. A fourth head is intended only to tune to 2211 MHz and uses a crystal-controlled local oscillator.

Being a coherent receiver, two inputs are required: A reference input obtained from the transmitter and a signal input.

Two outputs are obtained from the unit: an in-phase output and a quadrature output. Both are bi-polar.

Maximum noise figures for each band are listed below:

250-500 MHz	12 dB
500 MHz-1 GHz	14 dB
1 GHz-2GHz	16 dB
2211 MHz	18 dB

Four I. F. selectivities were provided originally: 1 MHz, 4 MHz, 8 MHz and 20 MHz. Only the 1 MHz is currently utilized.

Dynamic range is greater than 60 dB when the I.F. gain control is set for rated system sensitivity (Table III).

Since the receiver noise figures are high, separate pre-amplifiers having low noise figures (4.5 dB to 6.0 dB) are connected ahead of it so that the overall receiving system noise figure, including the coaxial connecting cables, is approximately 6.0 dB.

2.10 Antenna System for Large Targets

For large target testing, transmitting and receiving antennas are mounted on a 50-foot tower (Figures 7-8).

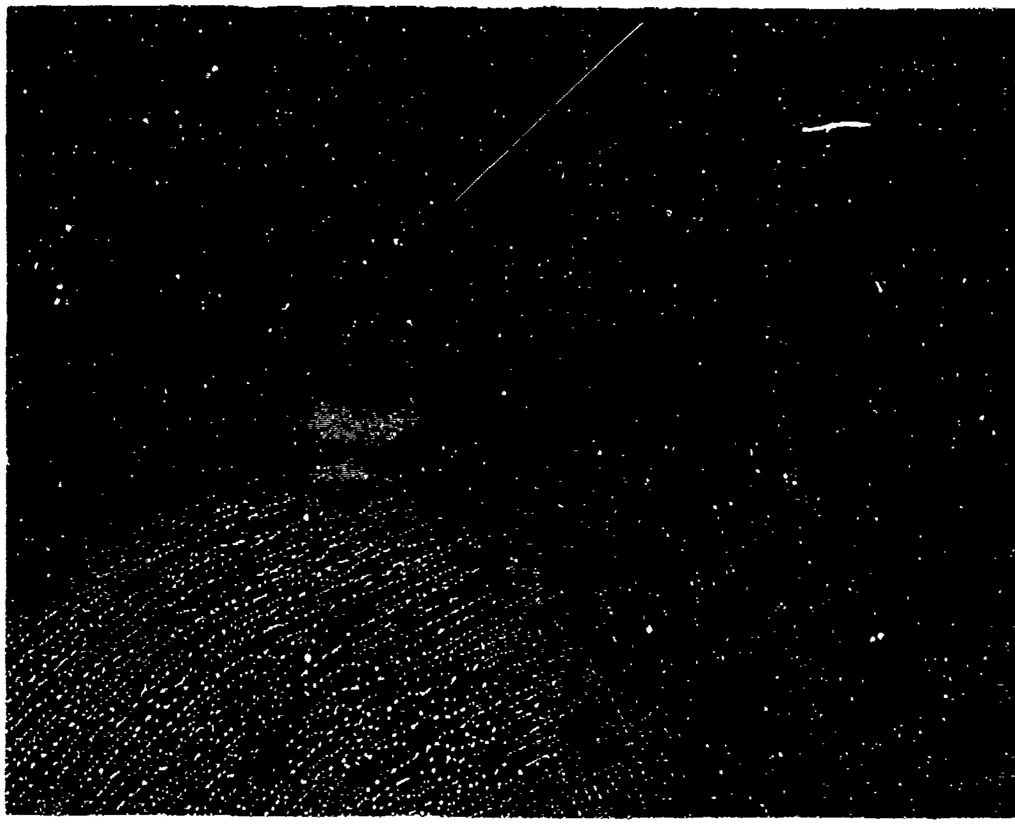

Figure 6 COHERENT RECEIVER

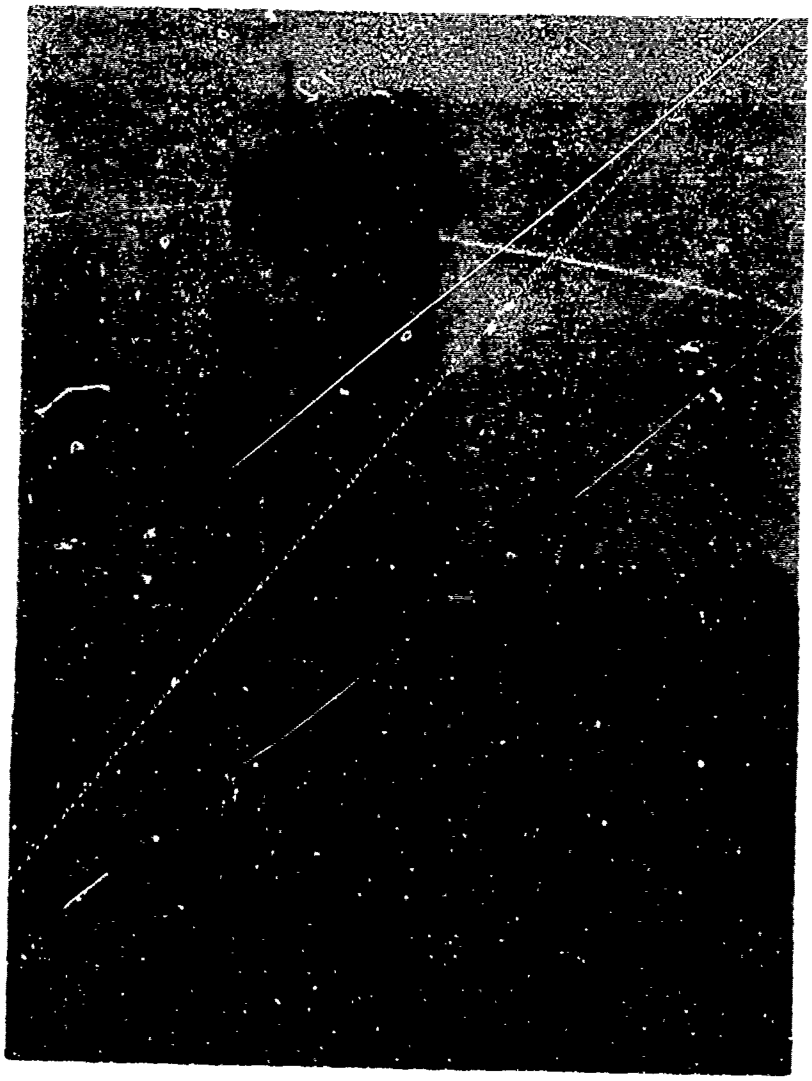

Figure 7 TOWER

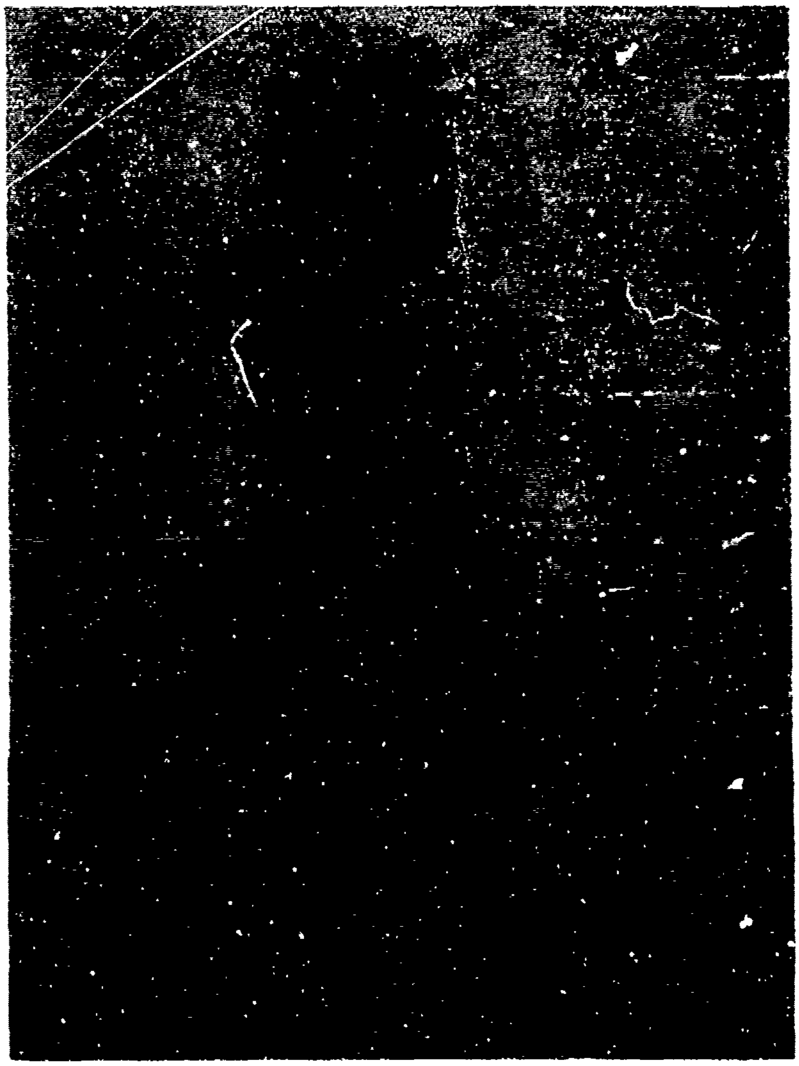

Figure 8 ANTENNA MOUNTED ON TOWER

One transmitting antenna is employed, a pyramidal log periodic, which is used to cover the complete transmitting range from 230 MHz to 737 MHz.

For stationary targets, two receiving antennas are used: A pyramidal log periodic which is used to receive frequencies below 1 GHz and a 3-foot dish fed by a pyramidal log periodic which is used to receive frequencies above 1 GHz. For moving targets, the pyramidal log periodic is used over the entire receiving frequency range.

The transmitting antenna is connected to the VP-METRRA vehicle by means of 125 feet of 7/8-inch diameter copper Heliax which is pressurized with dry air. A one-foot jumper cable constructed from RG-9B/U coaxial cable is used to connect the Heliax to the RF output connector on the side of the VP METRRA vehicle and to provide a degree of strain relief. At the antenna end of the Heliax, a five-foot length of 1/2-inch superflexible Heliax is used for connection to the transmitting antenna.

The antennas are mounted on the tower top so that they are pointing 25 degrees downward from horizontal.

Receiving antenna connections at vehicle and antenna are similar. However, a metal box containing receiving pre-amplifiers (Figs. 9-10) is physically located at the base of the tower. Electrically, this box is connected in the receiving antenna coaxial line.

The pre-amplifier box contains three amplifiers, 16 fixed coaxial filters, a blower, an adjustable attenuator controlled by switches inside the van, two power supplies and various manually-operated coaxial switches. The adjustable attenuator prevents overloading of the receiver. The power supplies provide power to the 250-1000 MHz and 1000-2000 MHz solid-state pre-amplifiers(the 2-6 GHz travelling-wave tube amplifier is powered by the 120 VAC,

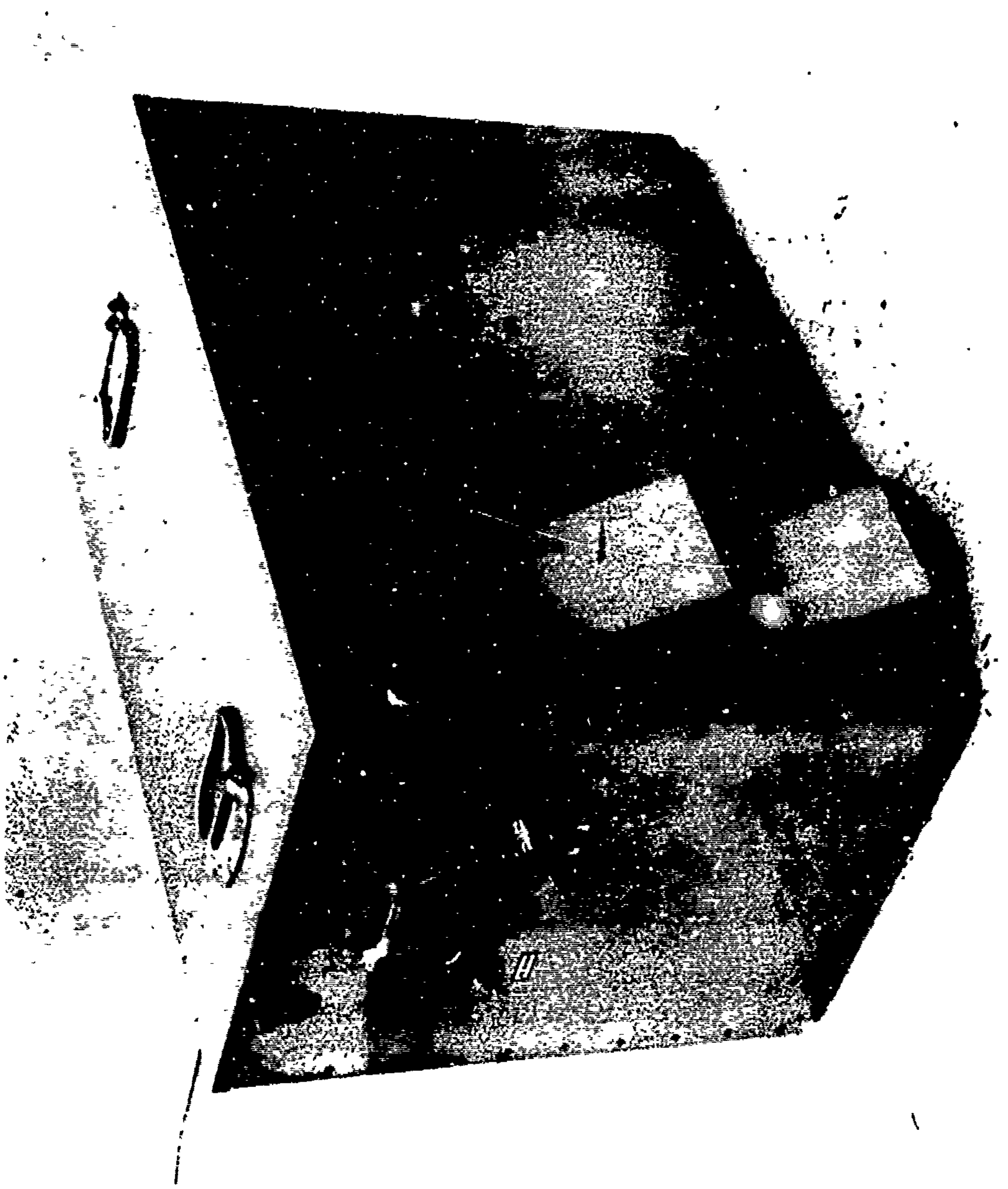

Figure 9 PRE-AMPLIFIER BOX

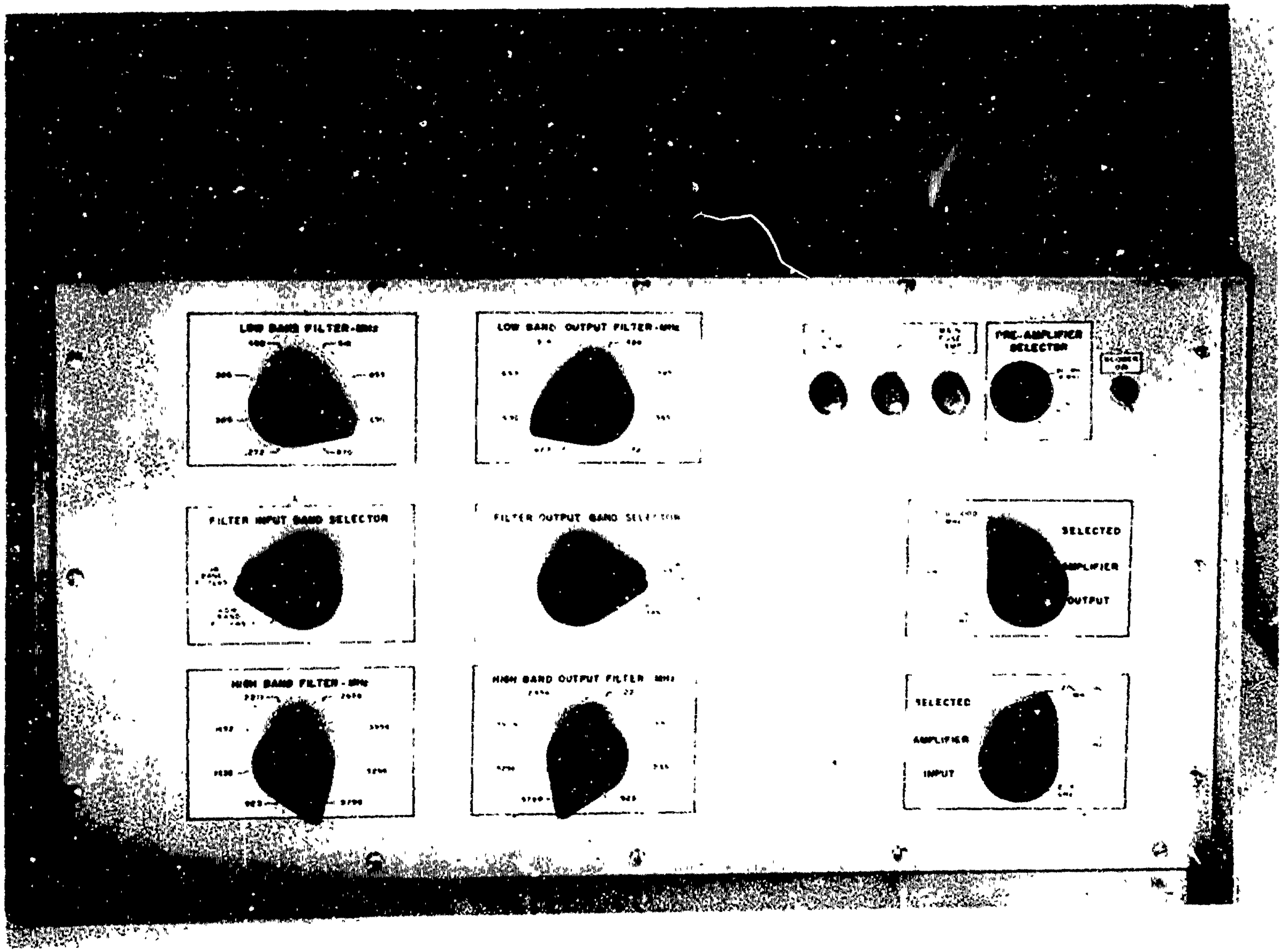

Figure 10 PRE-AMPLIFIER BOX WITH COVER REMOVED

60 Hz line).

2.11 Antenna System for Small Targets

For small targets, antennas mounted on eight-foot posts are used (Figure 11). One pyramidal log periodic antenna is used for transmitting over the range from 230 MHz to 737 MHz. For receiving, a pyramidal log periodic antenna is used up to 1 GHz. Above this frequency, an 18-inch dish fed by a pyramidal log periodic is used.

Figure 11 also shows (right side of picture) the frame constructed for testing small targets.

The transmitting antenna is connected to the VP METRRA van by means of 75-feet of 7/8-inch diameter copper Heliax which is pressurized with dry air. One-foot lengths of RG-9B/U coaxial cable are used to connect the Heliax to the van and to the transmitting antenna.

The selected receiving antenna is connected to the pre-amplifier box by means of a seven-foot length of 1/2-inch superflexible Heliax. The pre-amplifier box is connected to the van by means of a 75-foot length of 7/8-inch Heliax. One-foot lengths of RG-9B/U coaxial cables are used at each end of the long cable.

2.12 Data Recording System

Figure 12 depicts a simplified block diagram of the data recording system. A Central Processing Unit (CPU) is the nucleus of the data system.

The CPU, interface unit, Reader/Punch and the tape transport are located in the equipment racks; the teletype unit is located on the workbench/table.

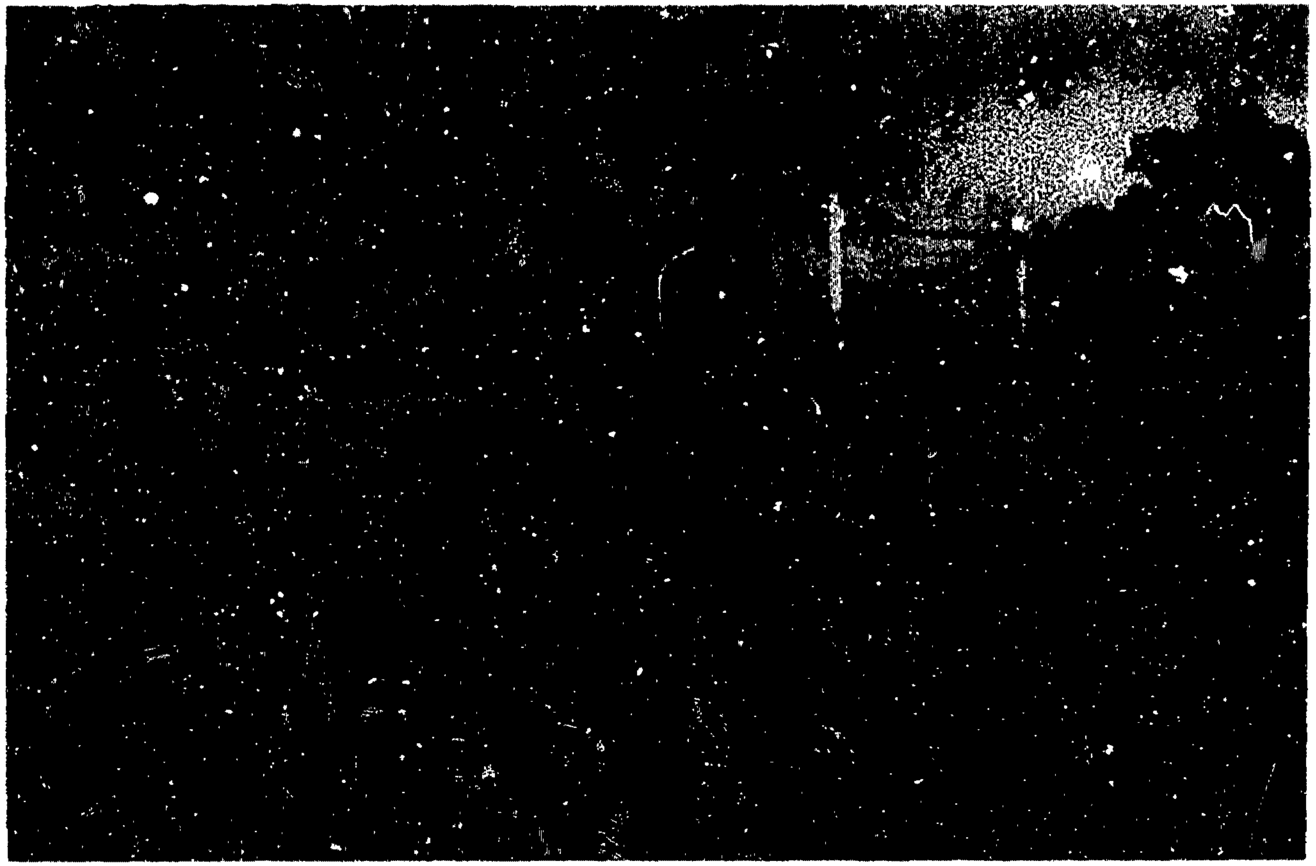

Figure 11 ANTENNA SYSTEM FOR SMALL TARGETS

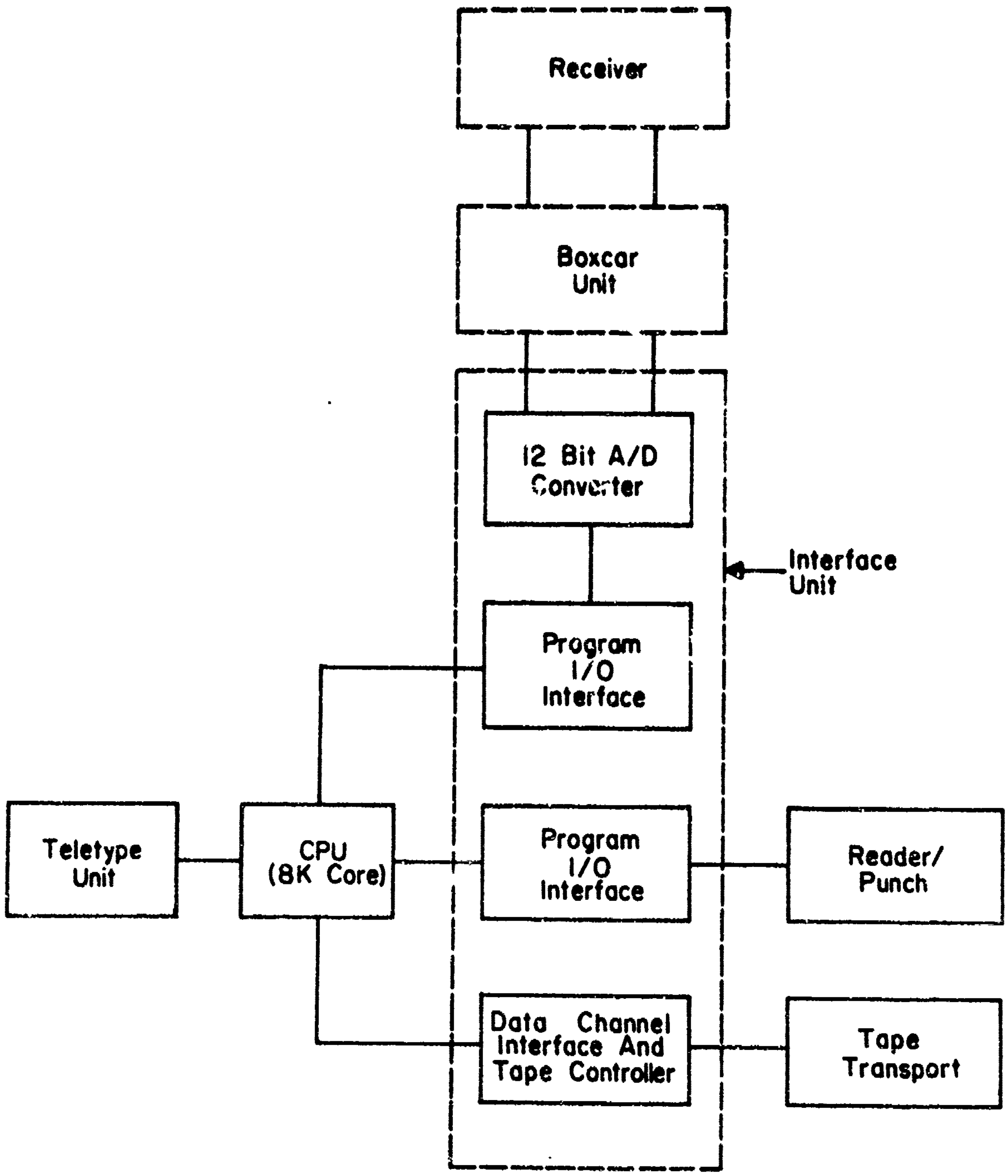

Fig. 12 SIMPLIFIED BLOCK DIAGRAM OF DATA SYSTEM

3. THEORY OF OPERATION

3.1 Simplified VP-METRRA System

Figure 13 shows the basic elements of the VP-METRRA system used for "harmonic" operation.

A selected frequency, f_o, is generated within the transmitter and may be either pulse of CW. The transmitter output power may be adjusted over a wide range, with a maximum of 100 watts CW or 5 kW pulse. Output from the transmitter is fed through a 20 dB directional coupler which provides a reduced-level signal to the transmitter monitor. A transmitting bandpass filter is used to insure that the signal radiated from the antenna is "clean" and that the radiated output is free from harmonics and spurious radiation.

A supplementary output, the CW 3 f_o receiver reference, is derived from the selected frequency source within the transmitter and is fed to the coherent receiver's reference channel input.

A second supplementary output, the range gate pulse, is generated within the transmitter and is fed to the box-car unit.

When the f_o radiated energy from the transmitting antenna impinges upon a suitable target, 3 f_o signals are generated by nonlinear junctions located on the target and re-radiated (scattered). A portion of this re-radiated 3 f_o energy impinges upon the receiving antenna. It is then passed through a receiving bandpass filter which serves two purposes: it limits the bandwidth which is passed on and it drastically reduces the amount of transmitter fundamental signal, picked up by the receiving antenna, which enters the remainder of the receiving system.

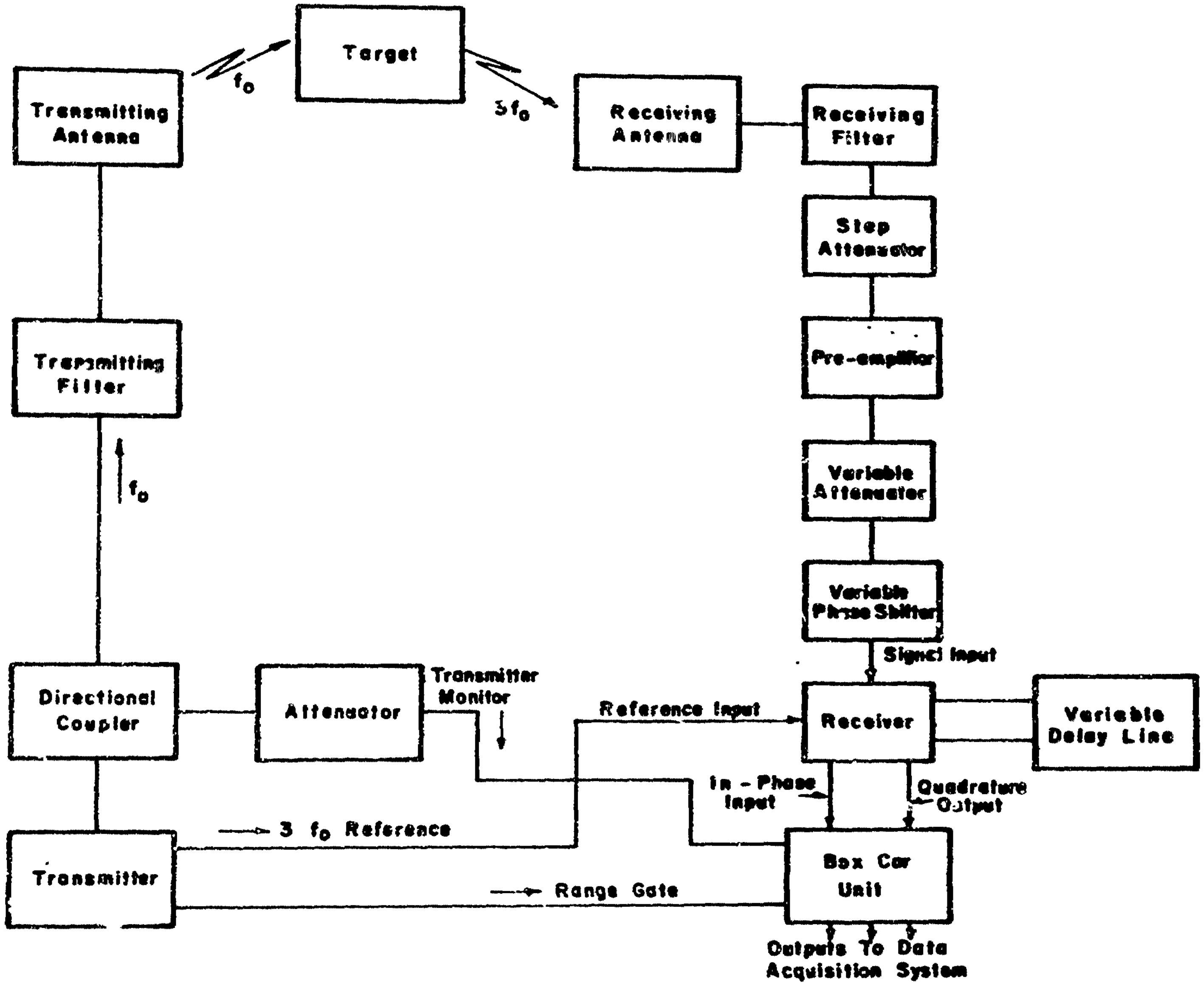

Fig. 13 SIMPLIFIED METRRA SYSTEM

Received energy passed through the receiving bandpass filter is attenuated remotely by the system operator if needed to prevent overloading of the selected pre-amplifier. Overloading is indicated when temporarily changing the signal input by a given amount, using the pre-amplifier attenuator, does not result in an equal change at the receiver output.

Amplified output from the pre-amplifier is again attenuated to adjust the signal level into the receiver. A variable phase shifter is used for calibration and permits the video output of the receiver to be adjusted to appear entirely in either the in-phase or quadrature channel. The variable delay line which is electrically connected in the receiver's internal reference channel circuitry permits compensation for differential delays within the receiver.

Two receiver outputs are obtained: one which is "in phase" and one which is in quadrature to this output. Amplitudes of these two outputs will depend upon the nonlinear junctions in the target. If the junction's outputs are variable, then the receiver's outputs will have variable amplitudes. If one output momentarily approaches a maximum, the other will simultaneously approach a minimum. Amplitudes of the two outputs will depend on the relative phase shift between the received signal and the reference signal.

Receiver outputs are narrow bi-polar pulses and are not suitable as inputs to a digital data recording system. Therefore, a boxcar unit has been incorporated to stretch the narrow bi-polar pulses into long rectangular bi-polar pulses having very low frequency components. Each spike is converted into a DC level which is maintained with "sample and hold" circuitry until the next pulse is sampled.

Range gate pulses from the transmitter gate the boxcar on at the precise times when the input pulse from the receiver is at its peak amplitude. The boxcar is off at all other times and blocks inter-pulse noise. An effective increase in signal-to-noise ratio results.

The boxcar unit also contains circuitry for monitoring the variation in transmitter output level and presenting it to the data acquisition system.

3.2 Transmitter

Refer to separately-bound operation and instruction manuals for the transmitter (two volumes plus portfolio of block diagrams and schematic drawings).

Since these transmitter manuals were written, the original tunable frequency sources have been replaced by five fixed crystal controlled frequency sources with fundamental frequencies of 230.0 MHz, 307.0 MHz, 436.1 MHz, 550.0 MHz and 737.0 MHz. Each frequency source has a power output adjustable between 200 and 400 milliwatts (adjusted from front panel of RF exciter unit of the transmitter). Each source has a third harmonic output with a nominal output of one milliwatt.

The original high-voltage power supplies were unregulated and were replaced with commercial highly-regulated supplies.

Heaters of the transmitting tubes were originally supplied with 6.3 VAC. Because of heater-induced hum, ripple and noise, the tubes had to be heated with highly-regulated 6.3 VDC.

Figure 14 shows RF circuitry between the output terminals on the transmitters and output terminals on the exterior of the van body.

Output from a transmitter passes through a 20 dB coupler and a low-pass filter. Output is switched to either a transmitting antenna or an internal dummy load. The 20 dB-decoupled output of the coupler (on the operating transmitter) is passed through a hybrid to a power meter.

Another output of the hybrid is passed through an attenuator. The output is detected and displayed on an oscilloscope. The transmitter pulse waveshape can be observed on the oscilloscope.

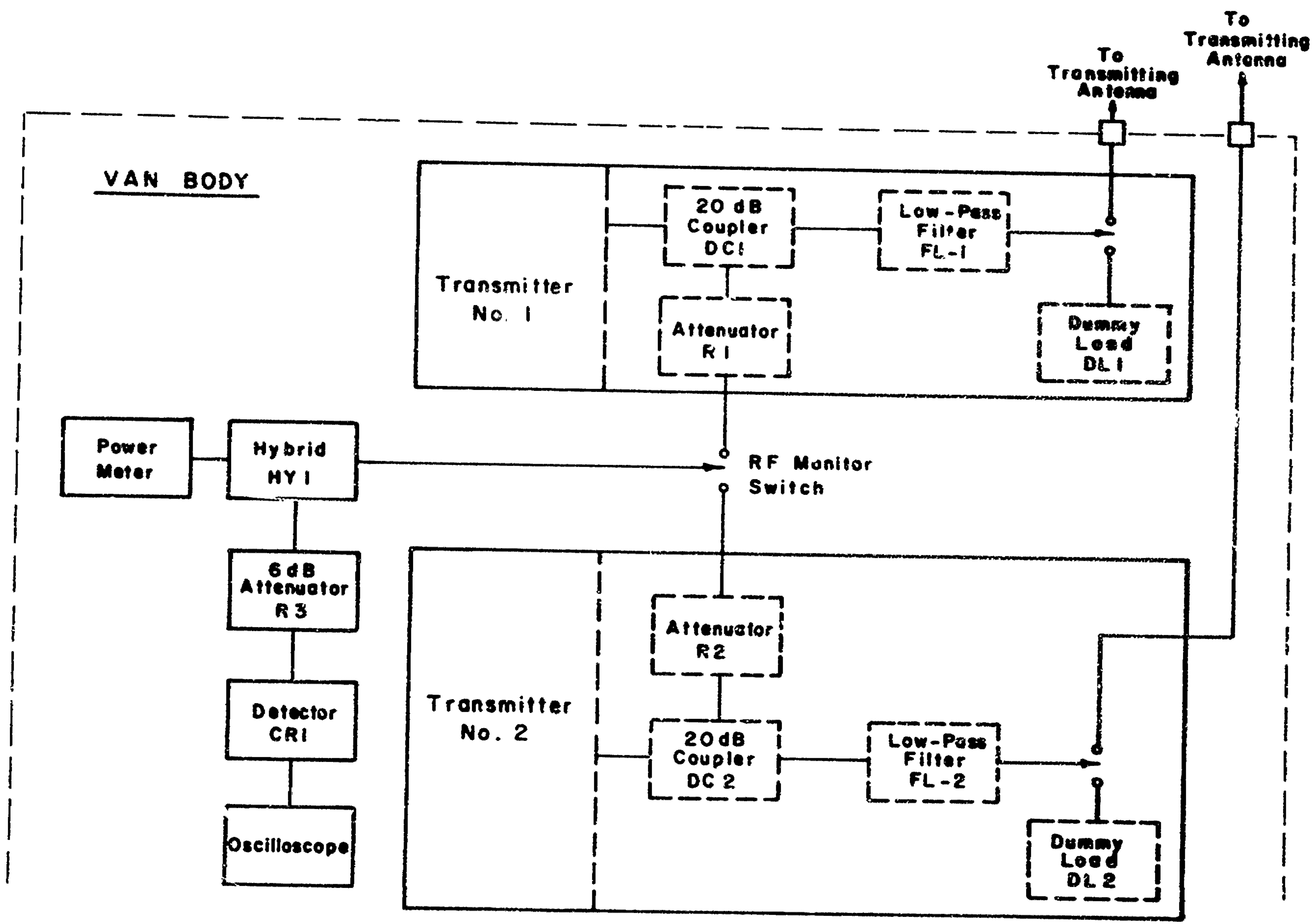

Fig. 14 TRANSMITTER OUTPUT CIRCUITRY

3.3 Receiver

3.3.1 Introduction

The difference between a coherent receiver and a non-coherent receiver is that a coherent receiver has an output that is dependent not only on signal amplitude but also on the relative phase of the signal with respect to a generated reference. The reference and the signal are of the same frequencies. A non-coherent receiver has an output that is dependent only upon signal amplitude. A coherent receiver has several potential advantages over a noncoherent receiver:

1. Signal-to-noise ratio (S/N) out of an envelope detector (noncoherent receiver) degrades with respect to input S/N for inputs having S/N of unity or less.

2. If integration is used, a greater integration efficiency is obtained with a coherent receiver.

3. High resolution target mapping, e.g., by use of synthetic aperture, requires coherent processing of the signal.

A coherent receiver is used in the VP METRRA System to determine whether returns from typical targets are coherent. If sufficient coherency exists, then future METRRA's can use coherent receivers and obtain the potential advantages.

Figure 15 shows the three main components of the SR-801 Receiver. As seen from the diagram, the reference is generated externally from the receiver. The component marked "Tuning Head" is the frequency selective part of the receiver. Here, both the RF signal and RF reference are converted down from RF to either 160 MHz or 60 MHz, depending upon the RF frequency.

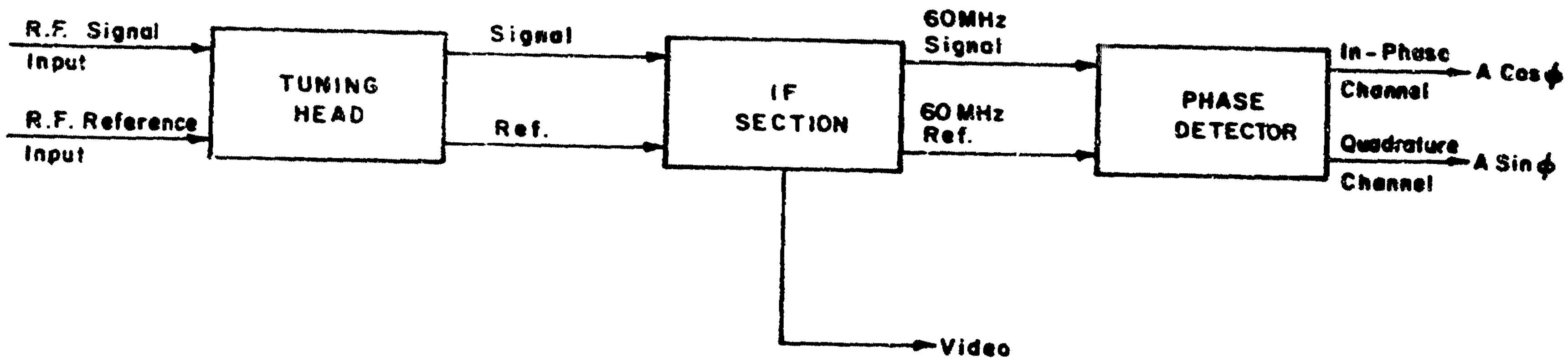

Fig. 15 RECEIVER GENERAL BLOCK DIAGRAM

The next part of the receiver is the IF section. In this section, the IF signal and IF reference are converted to 60 MHz, if they are 160 MHz, and amplified. This section also contains a noncoherent logarithmic video detector and a video output.

The last part of this receiver is the phase detector. It converts the information contained in the amplitude of the signal and the relative phase of the signal, with respect to the reference, into two output channels. One is called the in-phase channel and the other is called the quadrature channel.

3.3.2 Tuning Heads

3.3.2.1 500-1000 MHz Heads

Figure 16 shows the 500-1000 MHz tuning head in block diagram form. The signal first travels through the pre-selector. This is a tunable band pass filter whose purpose is to minimize interference. The signal is then fed to a mixer where the signal is converted to 60 MHz from RF. Then the signal is amplified by the pre-amplifier and finally fed to the IF section. The pre-amplifier is a 60 MHz tuned amplifier. A voltage-controlled oscillator is used as a local oscillator. Due to the specific power levels used, a wideband amplifier is necessary to feed the mixer in the reference channel. However, another important function of the wideband amplifier is to isolate the signal channel from the reference channel.

Because the RF reference input has a much greater power level than the signal, no pre-amplifier is necessary in the reference channel. Also, interference is no problem in the reference channel; therefore a pre-selector is not used here. The band pass filter is used to filter out unwanted mixing products from the mixer. In the signal channel,

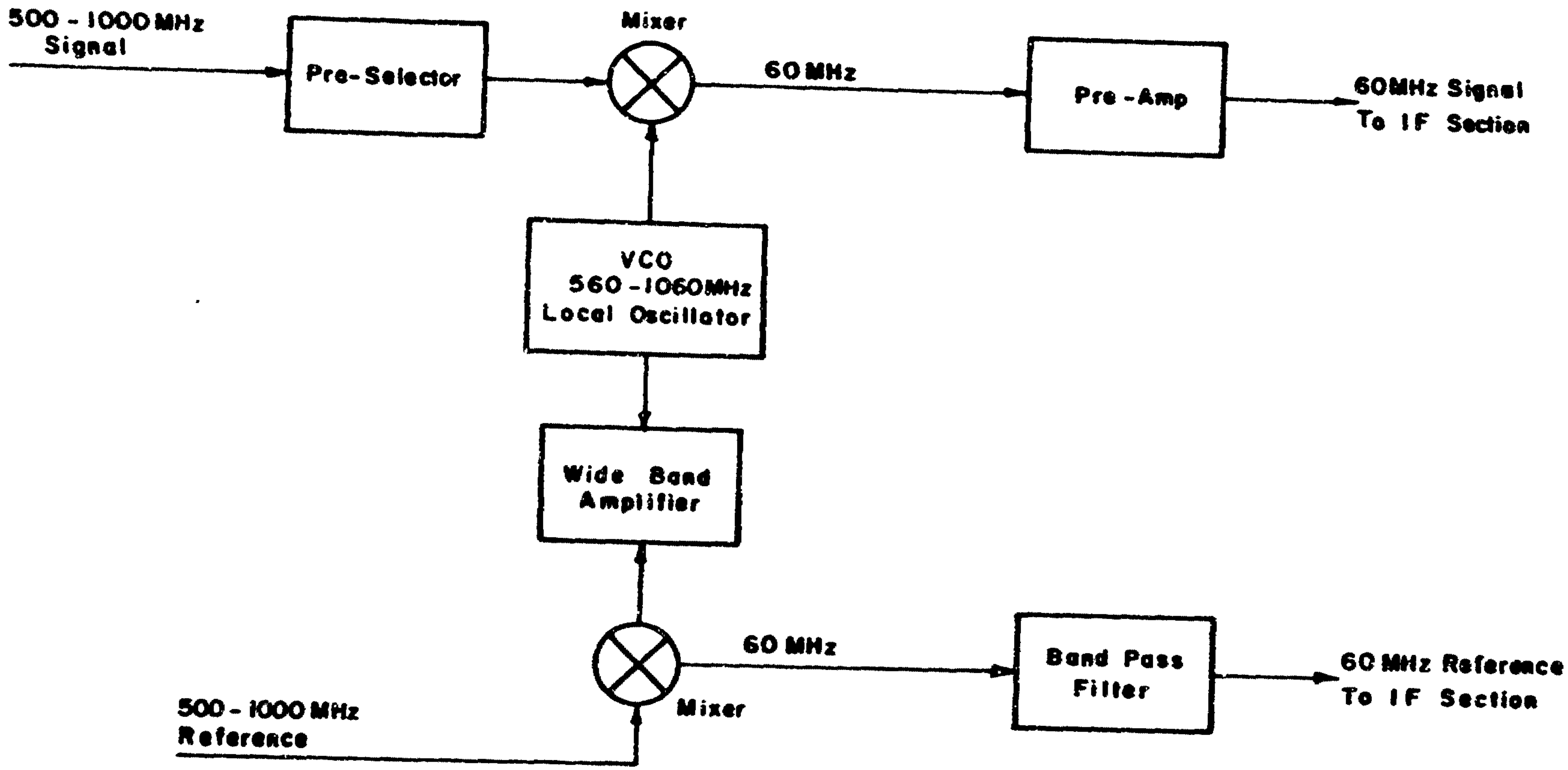

Fig. 16 500-1000 MHz TUNING HEAD

the pre-amplifier performs this function. The output of the bandpass filter in the reference channel is then fed to the IF section of the receiver for further processing.

3.3.2.2 1-2 GHz Head

The operation of the 1-2 GHz tuning head is shown in Figure 17. The entire operation of this head is similar to the operation of the 500-1000 MHz head. However, there are two differences. One difference is that the IF frequency is 160 MHz in this case whereas, in the 500-1000 MHz head, the IF frequency is 60 MHz. The other difference is that in the 1-2 GHz tuning head a bandpass filter is not used after the mixer in the reference channel. The reason for this is that the sum-of-the-frequencies term is so high in frequency (2160-4160 MHz) that the filtering in the IF section is adequate to attenuate this term enough for proper receiver operation.

3.3.2.3 2211 MHz Head

Figure 18 shows the operation of the 2211 MHz head in block diagram form. Here, the local oscillator is a 2371 MHz crystal-controlled unit. The two oscillators used for the other two heads are not crystal-controlled. Another difference between the 2211 MHz head and the other two heads is that no pre-selector and no pre-amplifier are used in the signal channel. The isolator prevents reference RF from getting into the signal channel. No isolator is required in the signal channel because the signal level is much lower than the reference level. It was found, however, that the 160 MHz reference was fed back into the signal channel. To eliminate this, it was necessary to put a high-pass filter into the local oscillator line feeding the signal channel mixer. A 1500 MHz high-pass filter does this adequately.

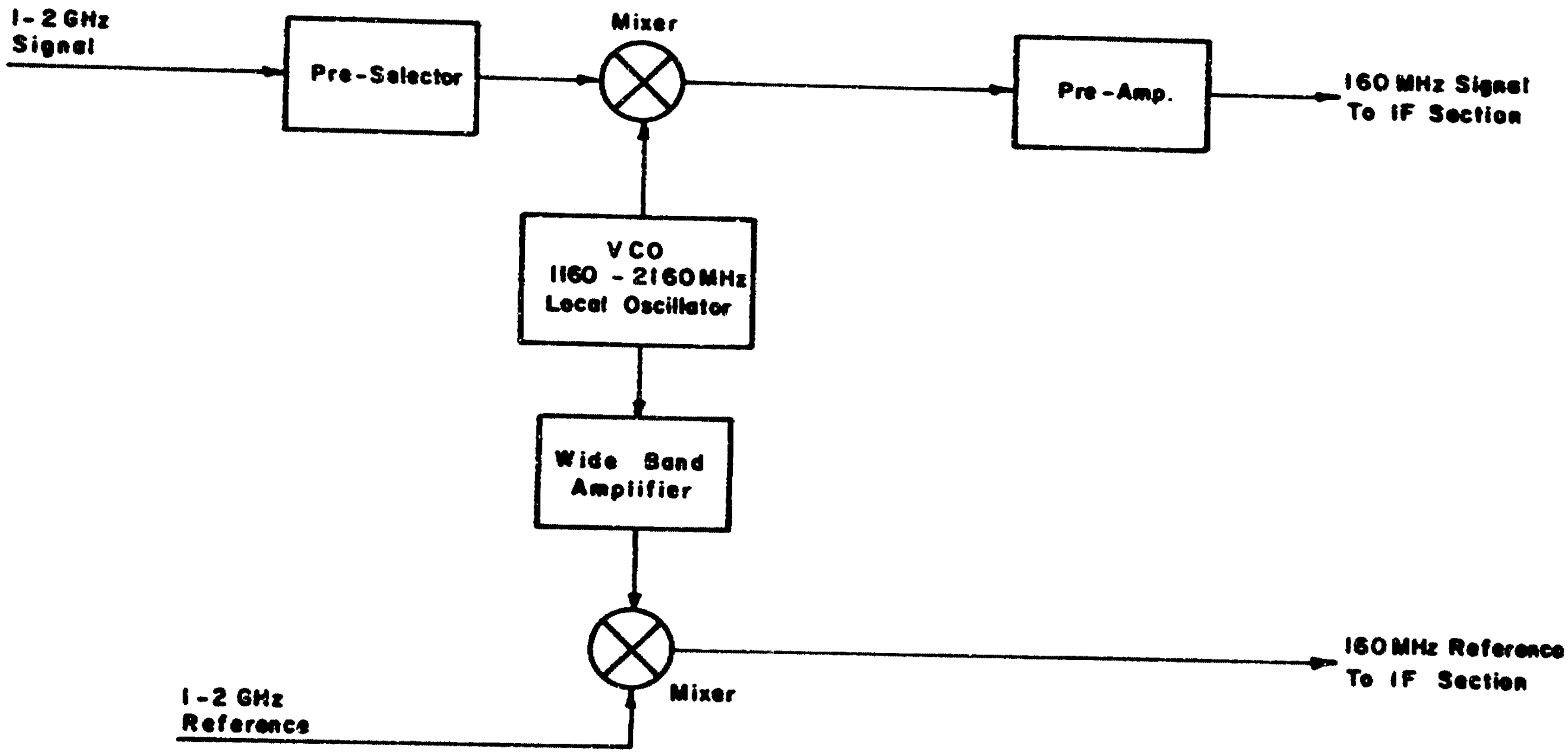

Fig. 17 1 - 2 GHz TUNING HEAD

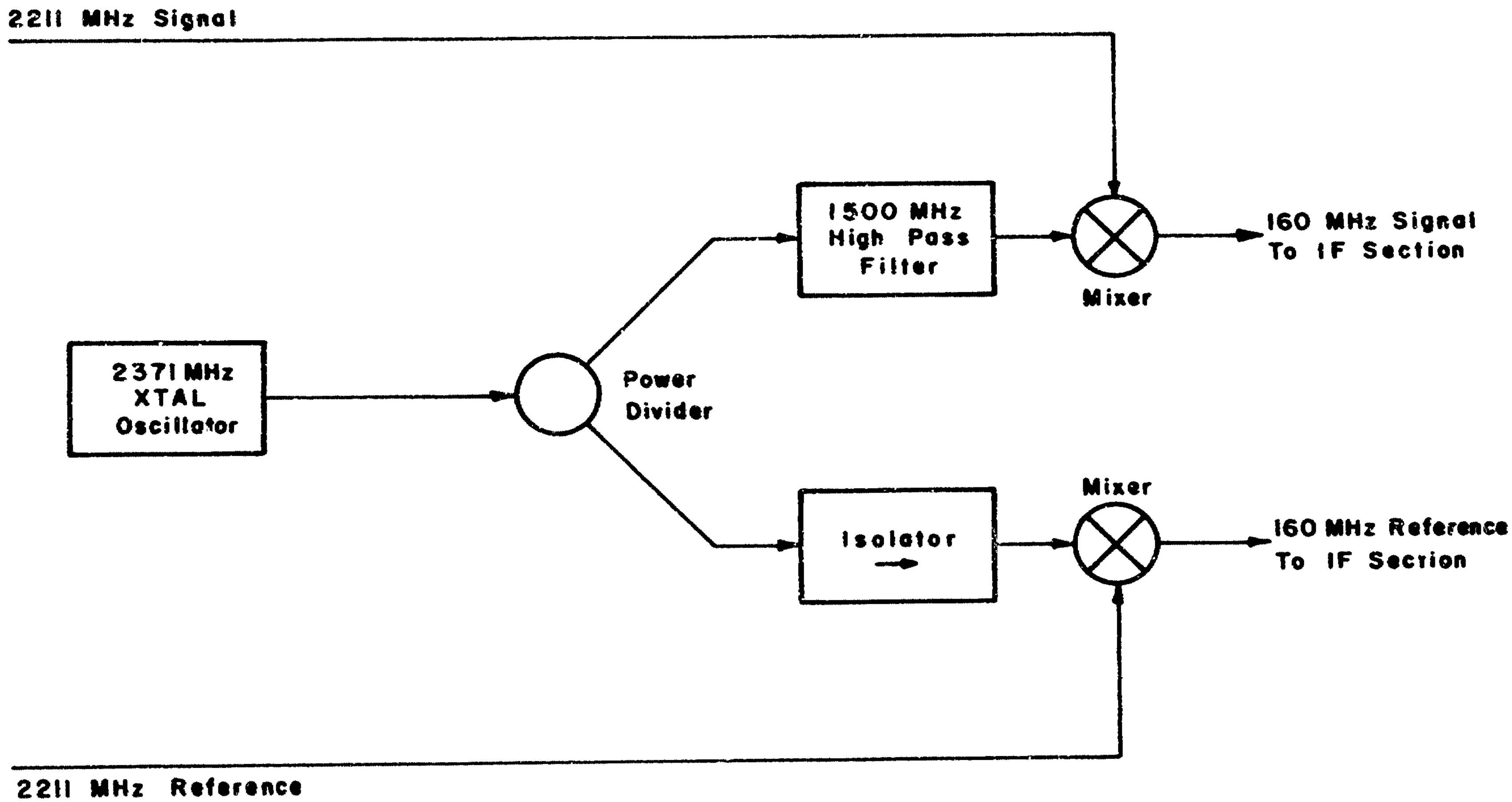

Fig. 18 2211 MHz TUNING HEAD

3.3.3 IF Section

The second major part of the receiver, the IF section, is shown in Figure 19. If the 500-1000 MHz head is being used in the receiver, the IF frequency is 60 MHz. The 60 MHz signal is fed from the tuning head through a coaxial switch to the first IF filter switch. The position of the coaxial switch is determined by the head being used. If either the 1-2 GHz head or the 2211 MHz head is used, then the coaxial switch would be in the other position from the one shown in the block diagram. The IF bandwidth can be either 1 MHz or 20 MHz. The bandwidth is selected through the use of the two IF filter switches. The 1 MHz bandwidth is determined by the bandpass filter, while the 20 MHz bandwidth is determined by the bandwidth of the linear IF amplifier. One output of the linear IF amplifier is fed to the phase detector, while another output is fed to a sucessive detection log IF amplifier. This amplifier also contains a video detector. The output of the log IF amplifier is then fed to a video amplifier. This video output is noncoherent; that is, the amplitude is not dependent upon the phase difference between the signal and the reference.

The reference signal is fed into a delay line and then into the IF amplifier. The delay line's purpose is to minimize changes in the phase difference between the signal and the reference that are due to frequency fluctuations of the local oscillator. That is, if d is the difference in delay between the signal channel and the reference channel, and f is the frequency fluctuation, then the variation in phase ϕ between the two channels is given by the following:

$$\phi = f \cdot d$$

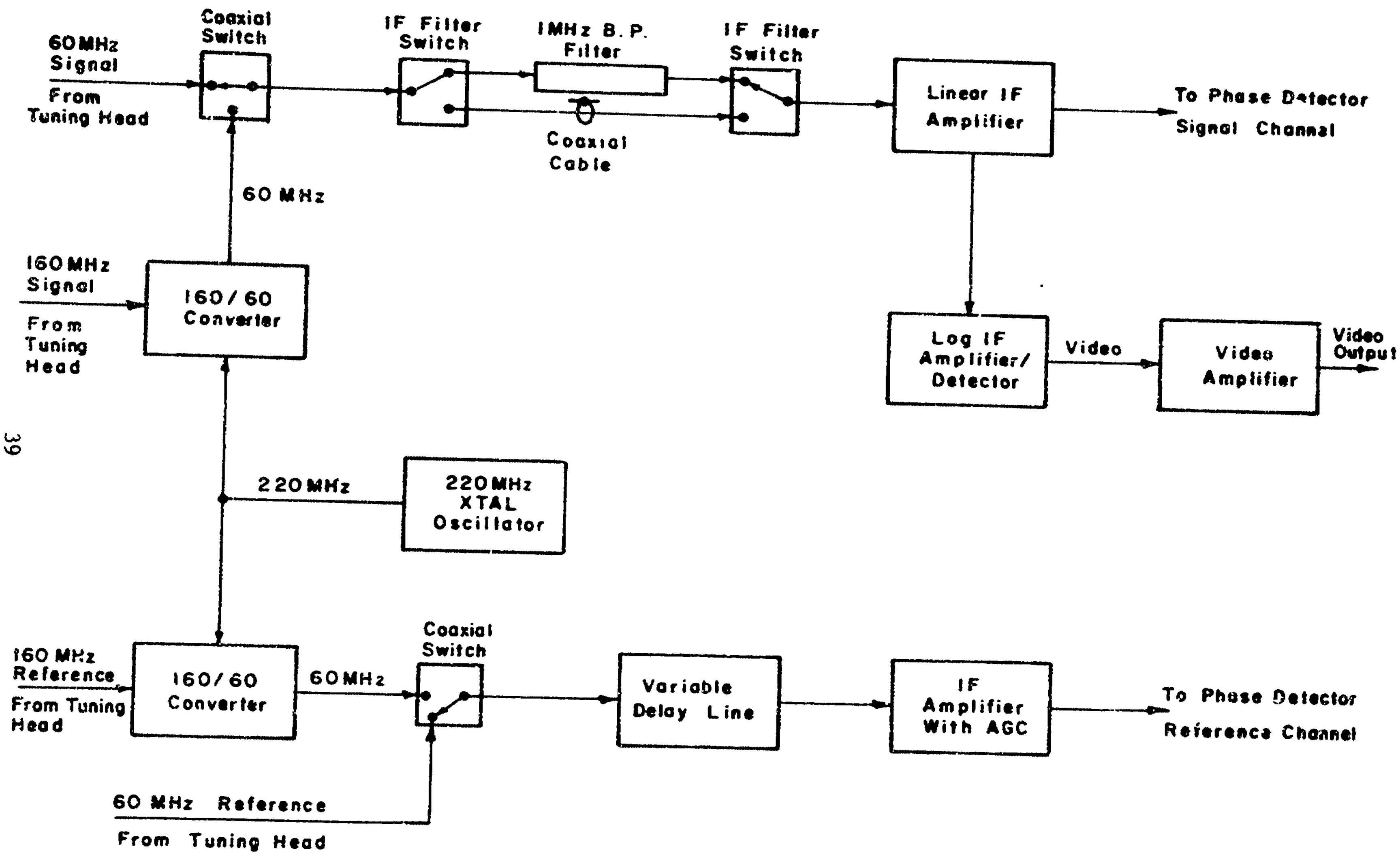

Fig. 19 I.F. SECTION BLOCK DIAGRAM

Thus, as d approaches zero, $\Delta\phi$ approaches zero. The output of the delay line goes to an IF amplifier with AGC. The reason for having AGC in the reference channel is to eliminate variations in the phase detector output (receiver output) that would certainly be there if the reference level would vary at the input to the phase detector.

If the 1-2 GHz or the 2211 MHz head were used, as mentioned above, the IF frequency out of the tuning head would be 160 MHz. According to Figure 19, the signal and the reference would be fed from the tuning head to two 160 MHz/60 MHz converters where the 160 MHz IF would be converted down to a 60 MHz IF. A 220 MHz crystal-controlled oscillator is used as a local oscillator for this conversion process. The coaxial switches in the signal and reference channels are switched automatically to connect the converter outputs to the rest of the receiver.

3.3.4 Phase Detector

So far, the signal has gone through processing that would be considered noncoherent. The processing that makes the receiver coherent takes place in the last section of this receiver. This section is called the phase detector and is shown in Figure 20. The signal is power split by a zero degrees power divider. That is, this power divider does not introduce phase shift to the signal. The reference is also power split, but one of the two outputs in this case is shifted ninety degrees with respect to the input. The other output has zero phase shift with respect to the input. Mathematically, the phase detector works as follows:

1. Assume the signal is CW and has a phase, ϕ, with respect to the reference signal = A sin (wt + ϕ). Both outputs of the zero degree phase shifter are A sin (wt + ϕ).

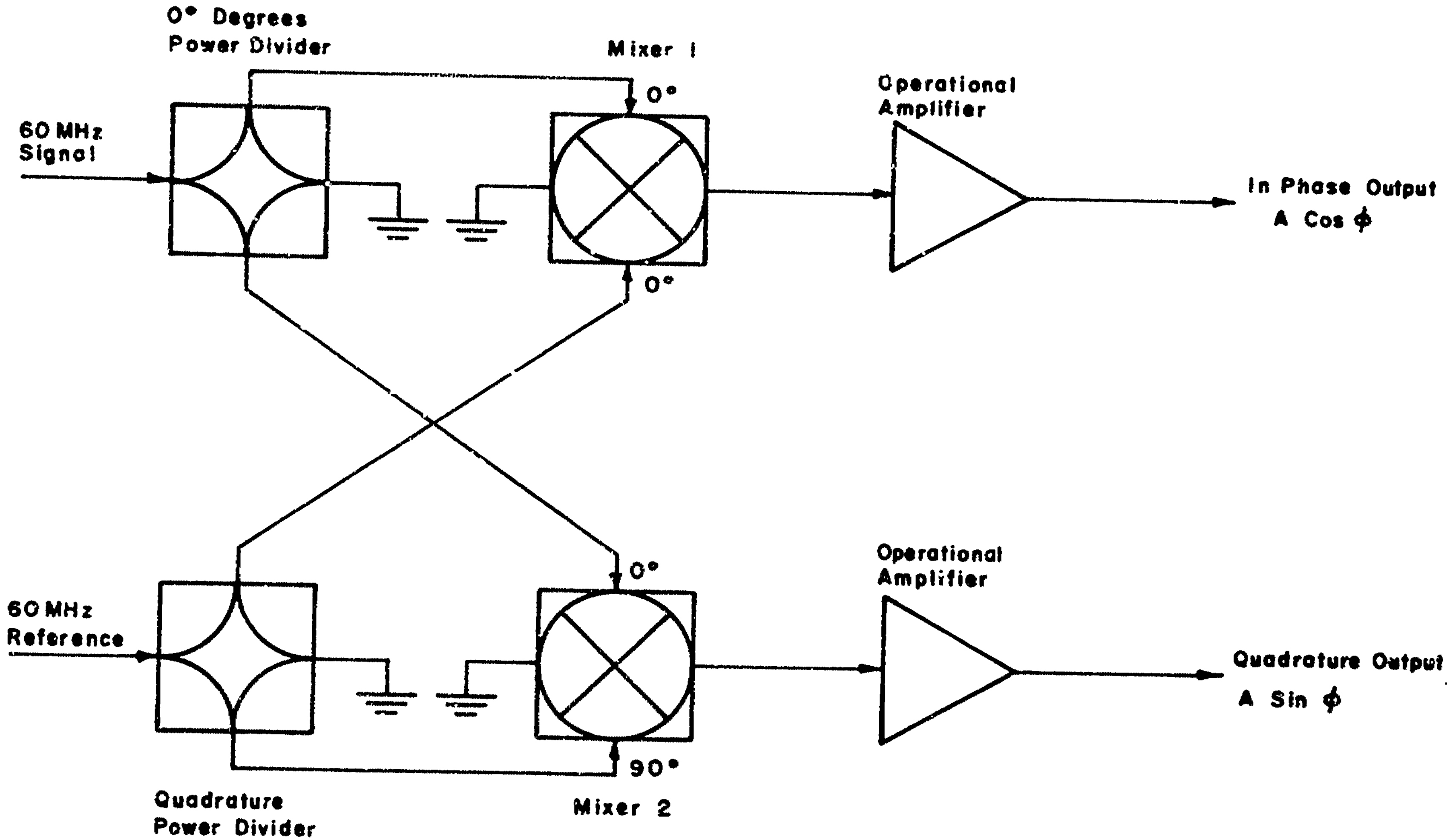

Fig. 20 PHASE DETECTOR BLOCK DIAGRAM

2. One output of the quadrature power splitter is B sin wt. The other is B sin (wt + 90°).

3. Therefore, the output of Mixer 1 in Figure 19 is as follows:

   $A \sin (wt + \phi) . B \sin wt$

   $= \frac{AB}{2} \left[\cos (wt + \phi - wt) - \cos (wt + \phi + wt)\right]$

   $= \frac{AB}{2} \left[\cos \phi - \cos (2\ wt + \phi)\right]$

   Cos $(2\ wt + \phi)$ is of such a high frequency (160 MHz) that it can be neglected. The operational amplifier filters this term out. Thus, the output of Mixer 1 is $\frac{AB}{2} \cos \phi$.

4. The output of Mixer 2 is:

   $A \sin (wt + \phi)\ .\ B \sin (wt + 90°)$

   $= \frac{AB}{2} \left[\cos (wt + \phi - wt - 90°) - \cos (wt + \phi + wt + 90°)\right]$

   $= \frac{AB}{2} \left[\cos (\phi - 90°) - \cos (2\ wt + \phi + 90°)\right]$

   Here, again, the term cos $(2\ wt + \phi + 90°)$ can be neglected.

   Therefore, the output is $\frac{AB}{2} \cos (\phi - 90°)$

   $= \frac{AB}{2} \left[\cos \phi \cos 90° + \sin \phi \sin 90°\right]$

   but $\cos 90° = 0$

   and $\sin 90° = 1$

   Therefore, the output of Mixer 2 is $\frac{AB}{2} \sin \phi$.

The above shows that if the signal is CW (the reference is always CW), the outputs of the receiver are DC terms that are shifted 90° with respect to each other. The same thing occurs when the signal is pulsed RF. When the pulse is there, the outputs of the phase detector are

video pulses whose amplitudes are $\frac{AB}{2}$ cos ϕ and $\frac{AB}{2}$ sin ϕ where again ϕ is the phase difference between the signal and the reference.

3.4 Boxcar Unit

3.4.1 Specifications:

Input $\pm$ 1 volt
Output $\pm$ 10 volts

Frequency response DC to 1.25 kHz 3 dB
Output down 60 dB at 2.5 kHz

Output Accuracy:

AC $\pm$ 3% + $\pm$ .7 dB passband ripple
DC $\pm$ 3% $\pm$ 10V to $\pm$ 50 mV
less than $\pm$ 50 mV $\pm$ 3% plus
$\pm$ 2 mV DC offset (short term)

Linearity .10%

Delay times:

Minimum delay time to hold, from trigger (positive transition) of 200 ns.

Maximum delay time to hold from trigger (positive transition) 3.0 microseconds.

Trigger requirements:

Positive voltage pulse; low voltage less than 0.5V; high voltage greater than 2.3V; rise time greater than 20 ns (note: unit will trigger on slower rise times but this will induce errors in output due to jitter).

3.4.2 Theory of Operation

One of the overall goals of the testing to be performed with the VP METRRA system is to permit the analysis

of temporal variations in the returned signals. Variations below approximately 1.25 kHz are of specific interest. Temporal variations of the signal returns appear as modulation on the in-phase and quadrature video outputs. The boxcar and associated filtering effectively select frequencies and provide gain for those components of the video signal between zero and approximately 1.25 kHz. In addition, the gated operation of the boxcar performs the receiver gating function to eliminate contributions from interpulse noise. A block diagram of one of the boxcar channels is given in Figure 21. The trigger pulse triggers a monostable multivibrator MS-1 with a variable pulse width (negative-going) of from 100 ns to 3.0 microseconds; this pulse triggers MS-2 which has a pulse width of 100 ns (see Figure 22). When MS-2 is low the output of the sample and hold module SHM-2 follows the input; when MS-2 goes high the SHM-2 output holds the value of the input at that instant and holds it. Because the SHM-2 is a high speed unit that can acquire a signal very quickly, its output has high droop, i.e., the output tends to go to zero very quickly. To solve this problem, another slower sample and hold with a low droop is used to hold the value of the SHM-2: this is theSHM-1 and it is triggered by MS-3 which is triggered by MS-2. MS-3 has a pulse width of 4.0 microseconds which is long enough for SHM-1 to acquire the signal on the output of SHM-2. The output of SHM-1 is filtered by a low pass filter with a cutoff frequency of 1.25 kHz; this filter removes all unwanted AC components from the output signal. The output of the low pass filter is amplified by an operational amplifier operated in the noniverting mode to a given gain of 10 so that the output is $\pm$ 10 volts for an input of $\pm$ 1.0 volt. Figure 23 is a schematic diagram of the boxcar unit.

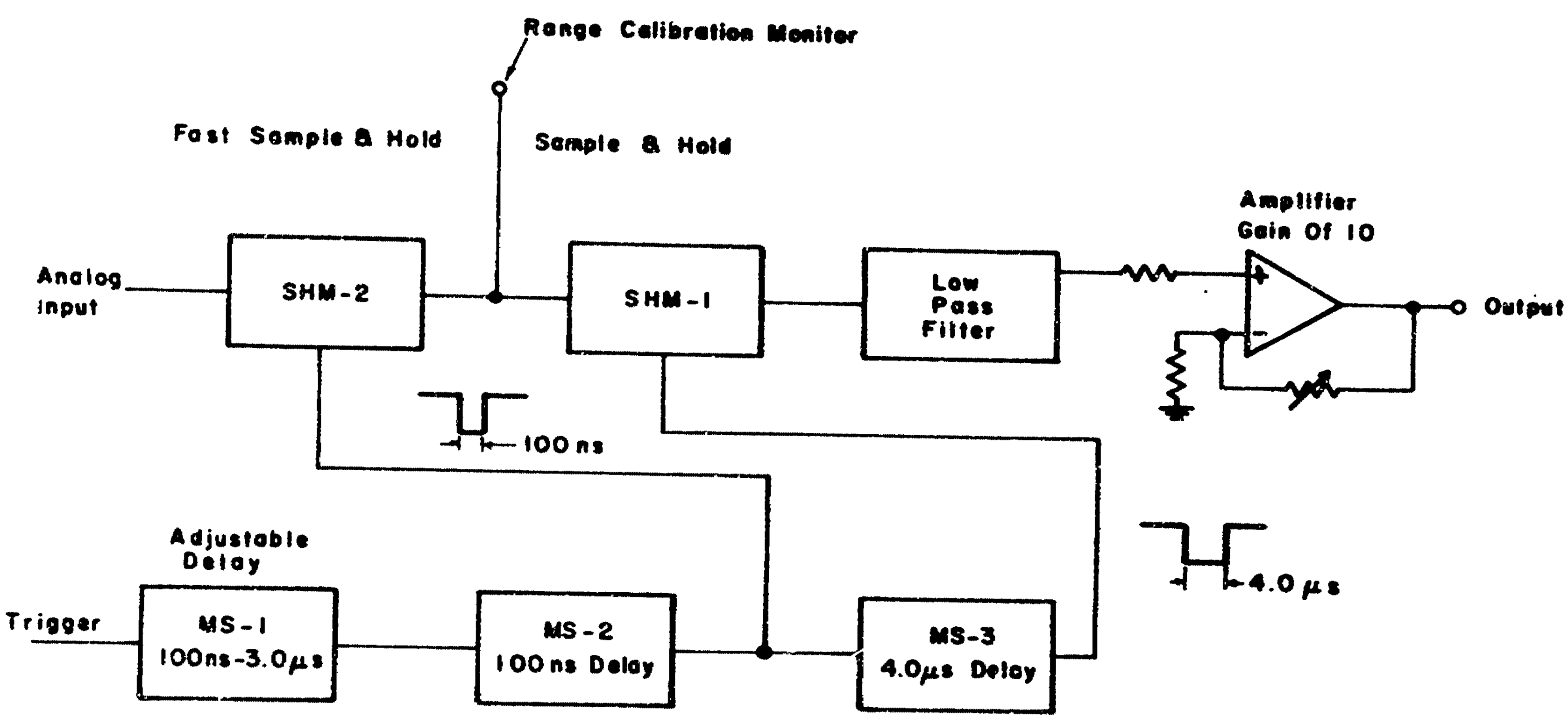

Fig. 21 BLOCK DIAGRAM OF ONE BOX CAR CHANNEL

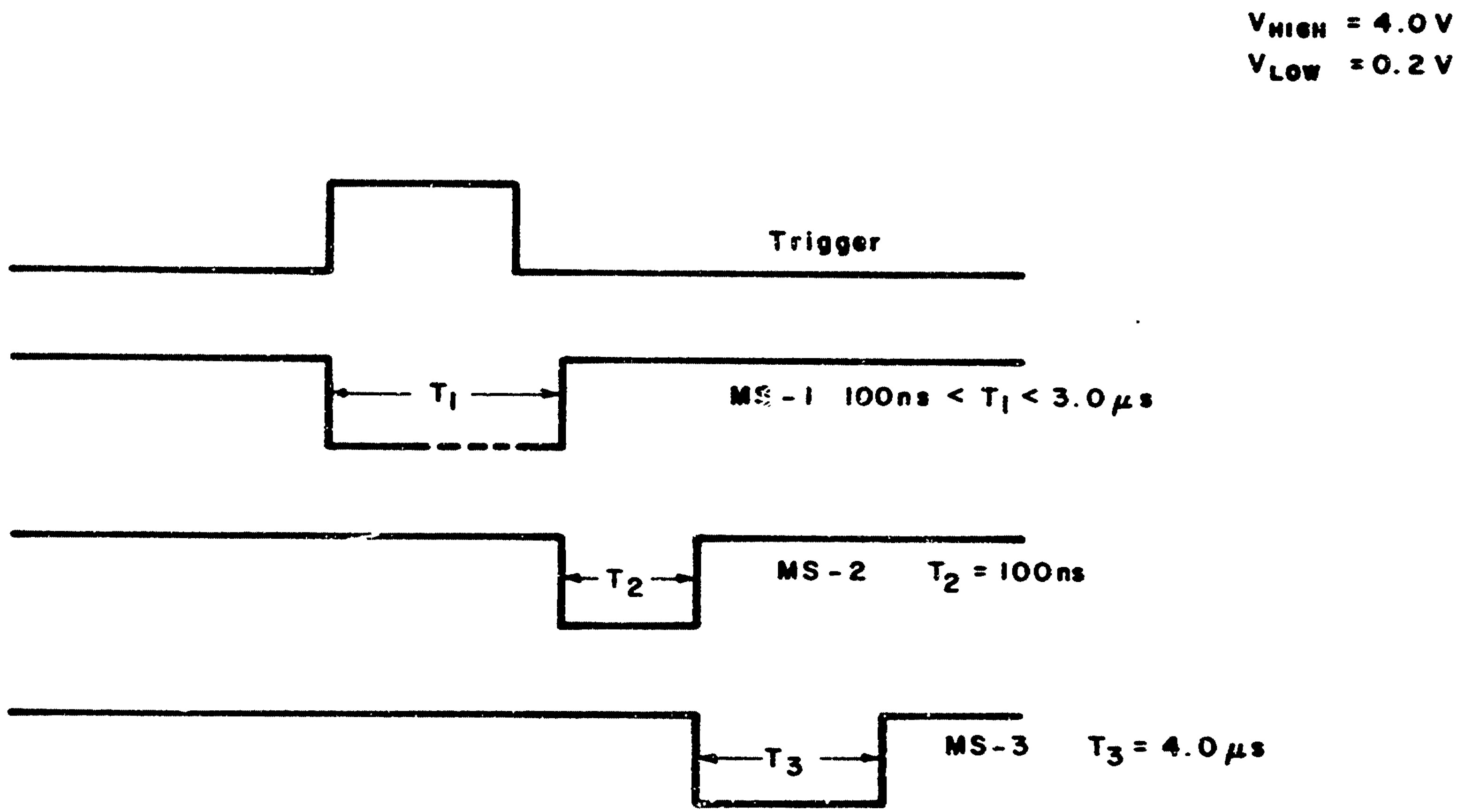

Fig. 22 TIMING DIAGRAM OF MONOSTABLE MULTIVIBRATORS

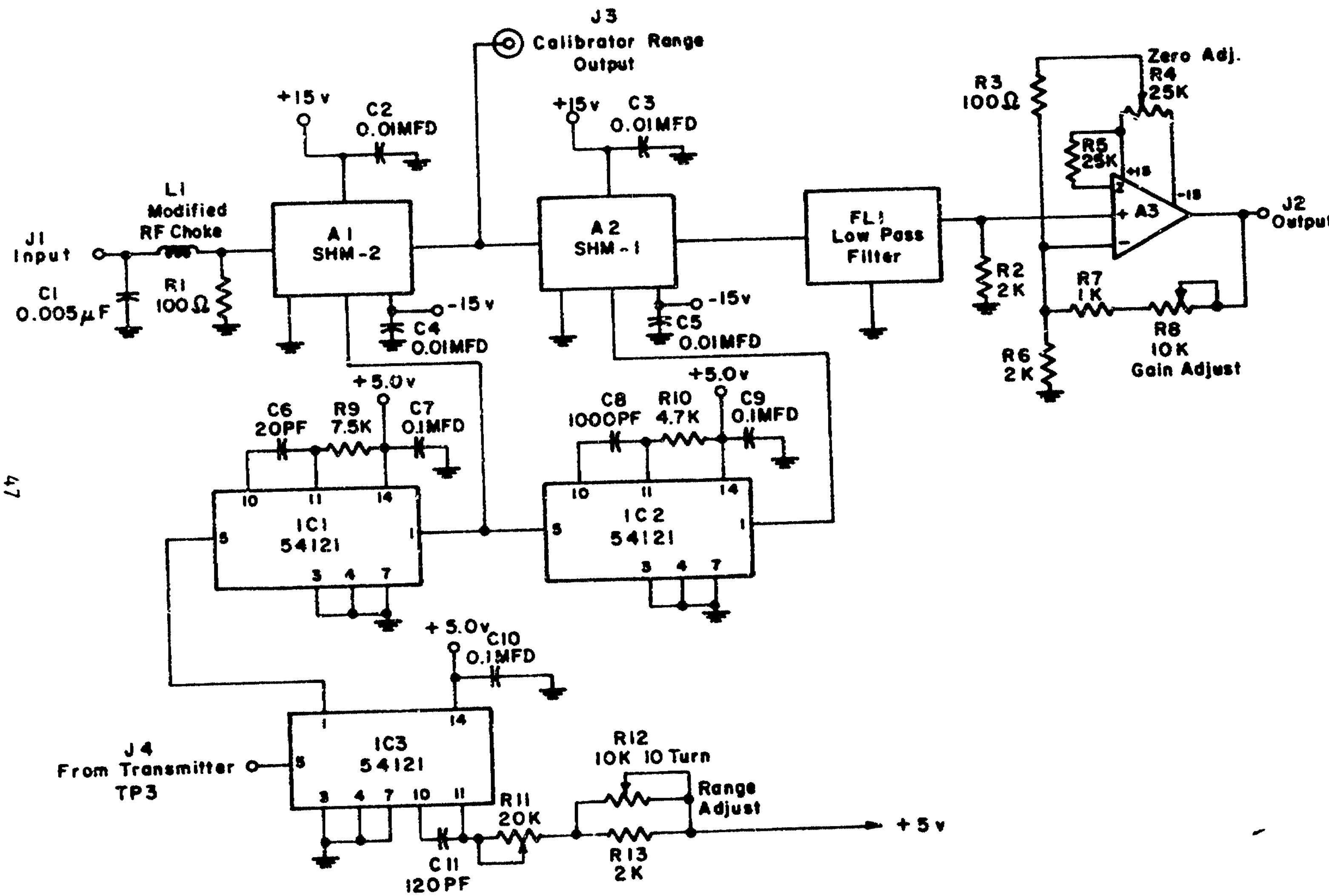

Fig. 23 SCHEMATIC OF BOXCAR UNIT

3.4.3 Transmitter Monitor

The transmitter monitor is physically located in the boxcar unit. It consists of a high-frequency crystal diode detector, two lowpass filters and an operational amplifier (Figure 24). The unit detects peak power in the range of 30 to 100 milliwatts (peak). It will also detect modulation on the transmitter signal from DC to 1 kHz minimum.

The monitor obeys the relationship:

$$V_{DC} = 37.0\ (0.25\ P + 0.002)$$

where P is peak power in milliwatts and V is in volts.

Figure 25 shows this relationship graphically.

The monitor provides a DC output proportional to the peak of the input power. As the RF level fluctuates due to transmitter arcing, temporary loss of transmitted signal, or presence of undesired modulation on the transmitted pulse, the variation (maximum and minimum) in peak pulse amplitude over the recording (data-taking) period is determined by the monitor. This information is eventually typed out by the teletype at the conclusion of the data-taking period.

3.5 Antenna Systems

Each antenna system (tower and "ground") uses only one broadband transmitting antenna to cover the entire frequency range.

For receiving (for stationary targets only with the tower antennas), small pyramidal log periodic antennas are used up to 1 GHz and parabolic "dish" antennas are employed above 1 GHz. The dishes are used to obtain higher

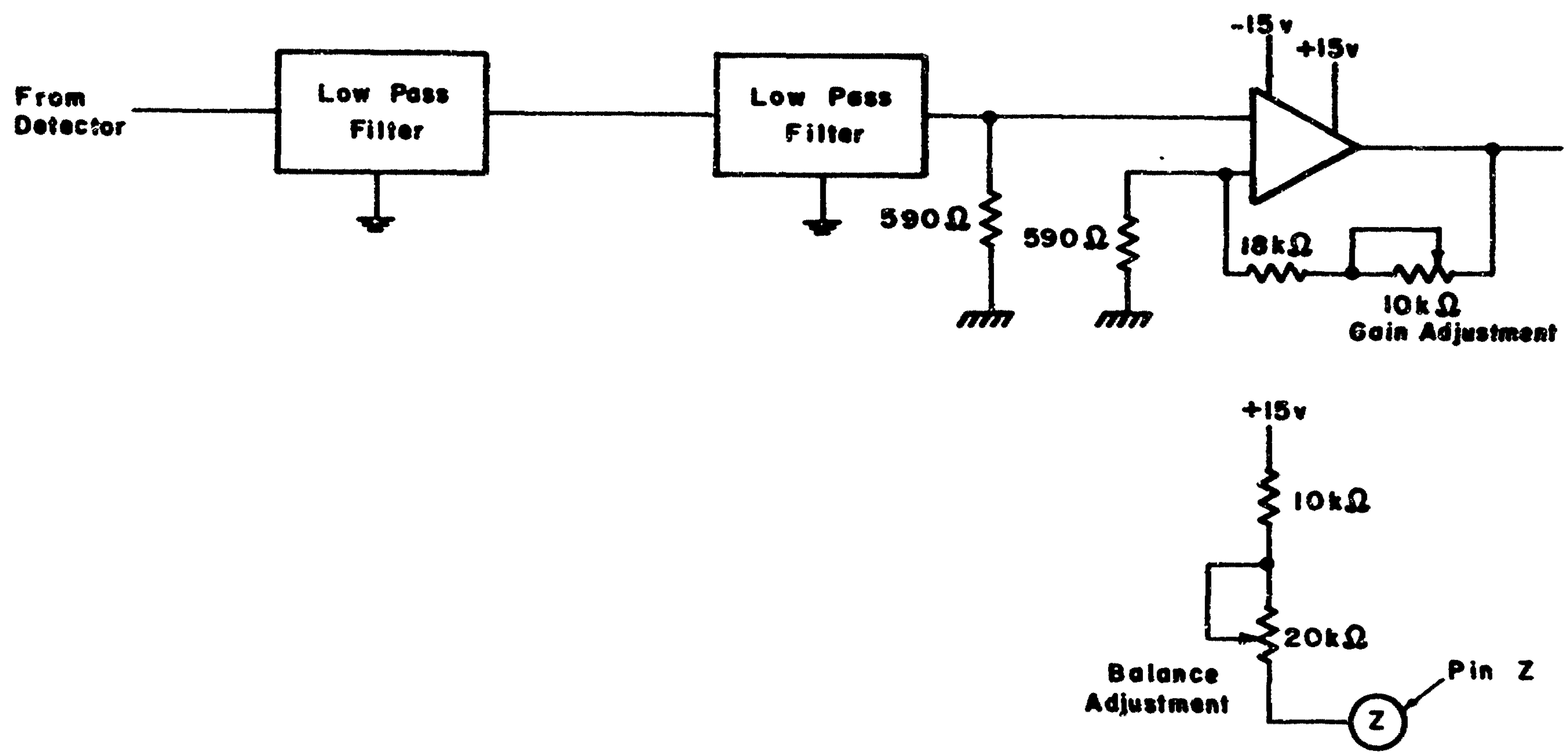

Fig. 24 SCHEMATIC OF TRANSMITTER MONITOR

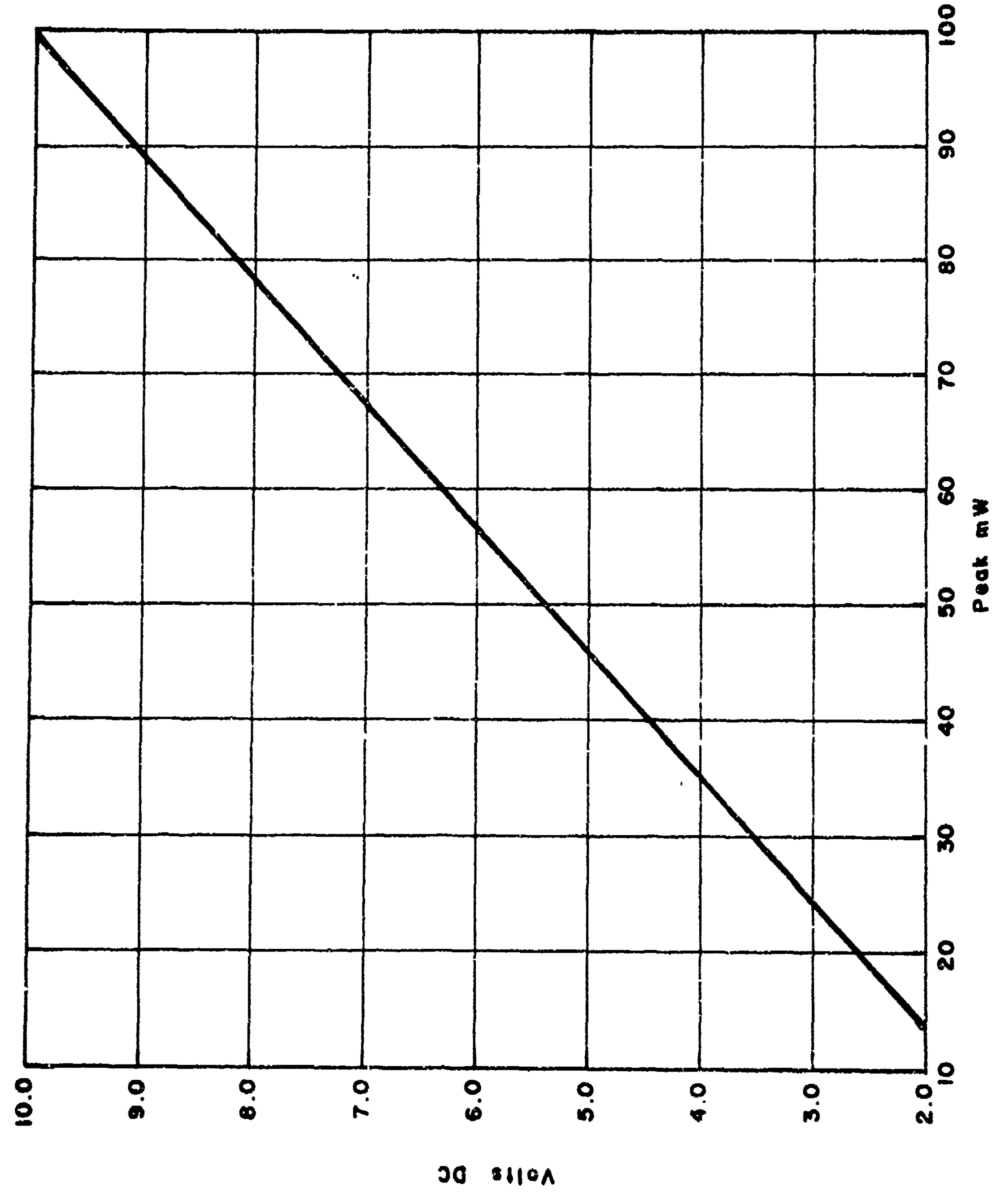

Fig. 25 DC OUTPUT VERSUS TRANSMITTER MONITOR INPUT

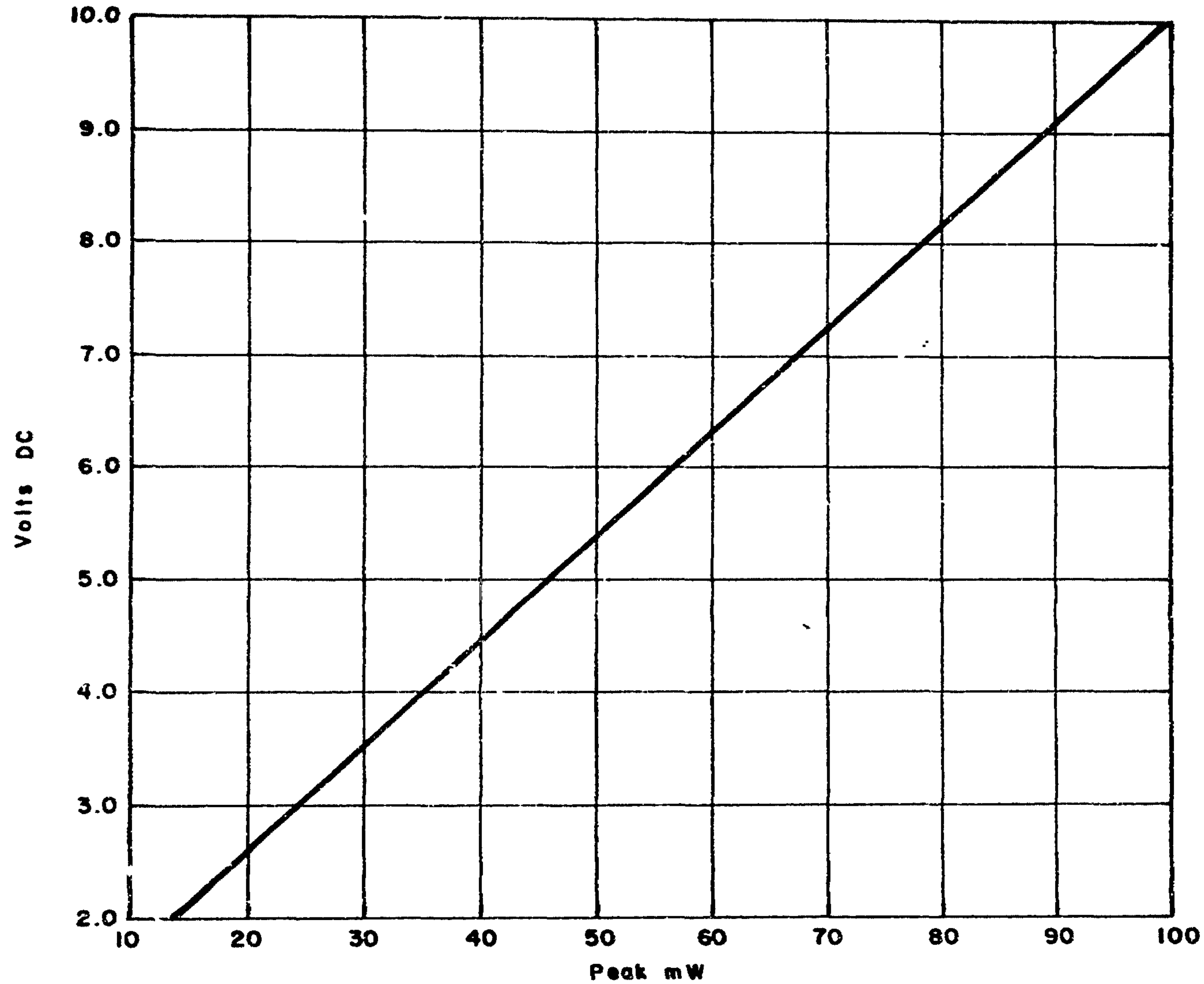

Fig. 25 DC OUTPUT VERSUS TRANSMITTER MONITOR INPUT

sensitivities through directionality at the higher frequencies.

When receiving third-harmonic signals from large moving targets (tower system), the small pyramidal log periodic antenna is used to cover the entire receiving frequency range because its beam is wide enough to cover the moving target throughout its range of movement. The dish antenna has too narrow a beamwidth for this application.

3.5.1 Pre-Amplifier Box

Figure 26 is a simplified block diagram of the preamplifier box.

A signal from a receiving antenna is passed through a bandpass filter connected at the box input. This filter primarily blocks transmitted energy picked up by the receiving antenna.

Within the box, the remotely-controlled attenuator prevents overloading of the preamplifiers.

For receiving frequencies between 250 and 1000 MHz, the 1-2 GHz and 250-1000 MHz preamplifiers are connected in cascade to provide additional gain. The 20 dB pad is used to reduce this additional gain to the amount desired.

3.6 Power System

Figure 27 is a block diagram of the power system. This system includes selection of primary power source, under-frequency and overvoltage monitoring and protection, air-conditioning system power and control circuitry, and application of primary power to the van and equipment.

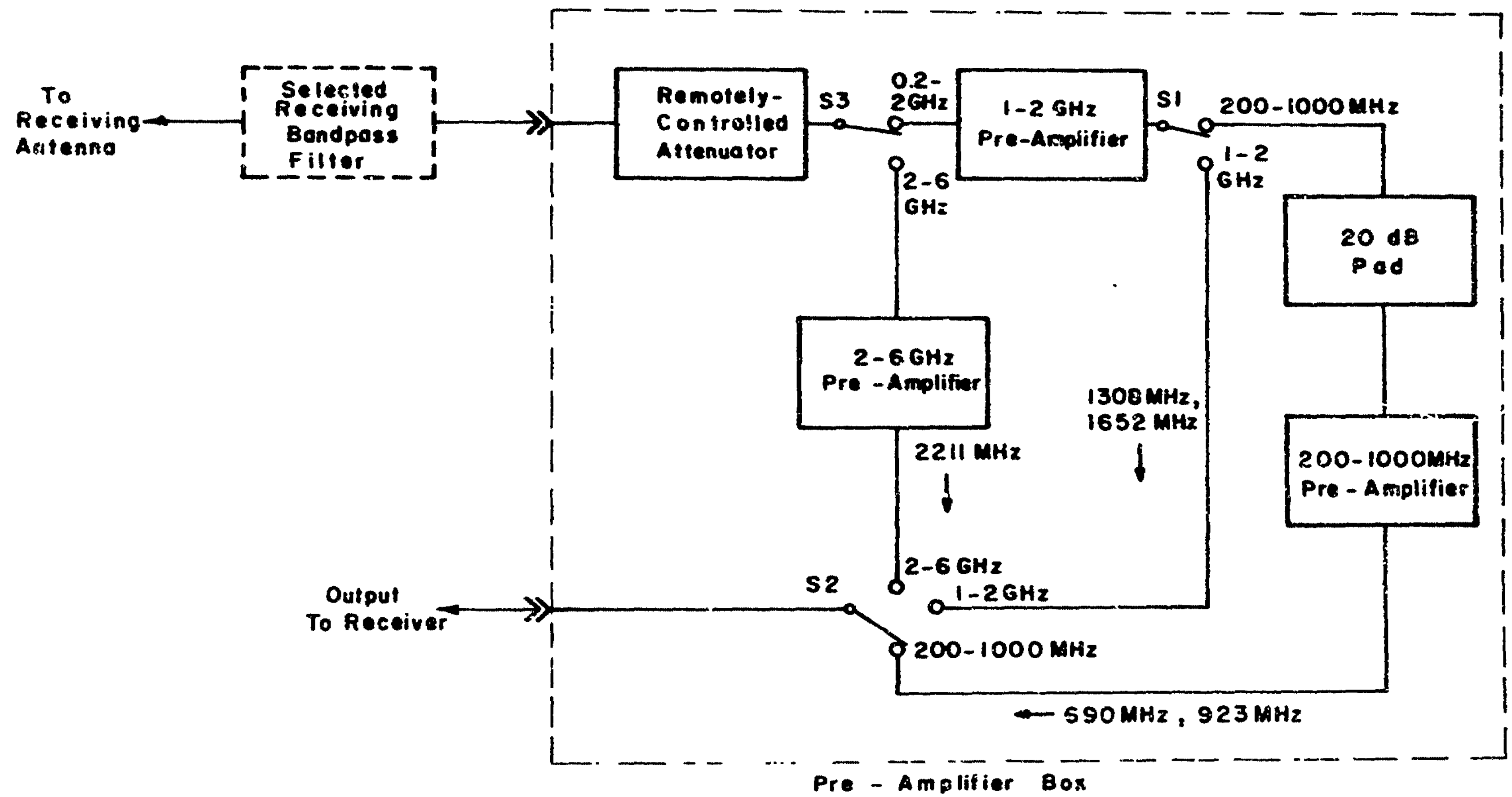

Fig. 26 SIMPLIFIED BLOCK DIAGRAM OF PRE-AMPLIFIER BOX

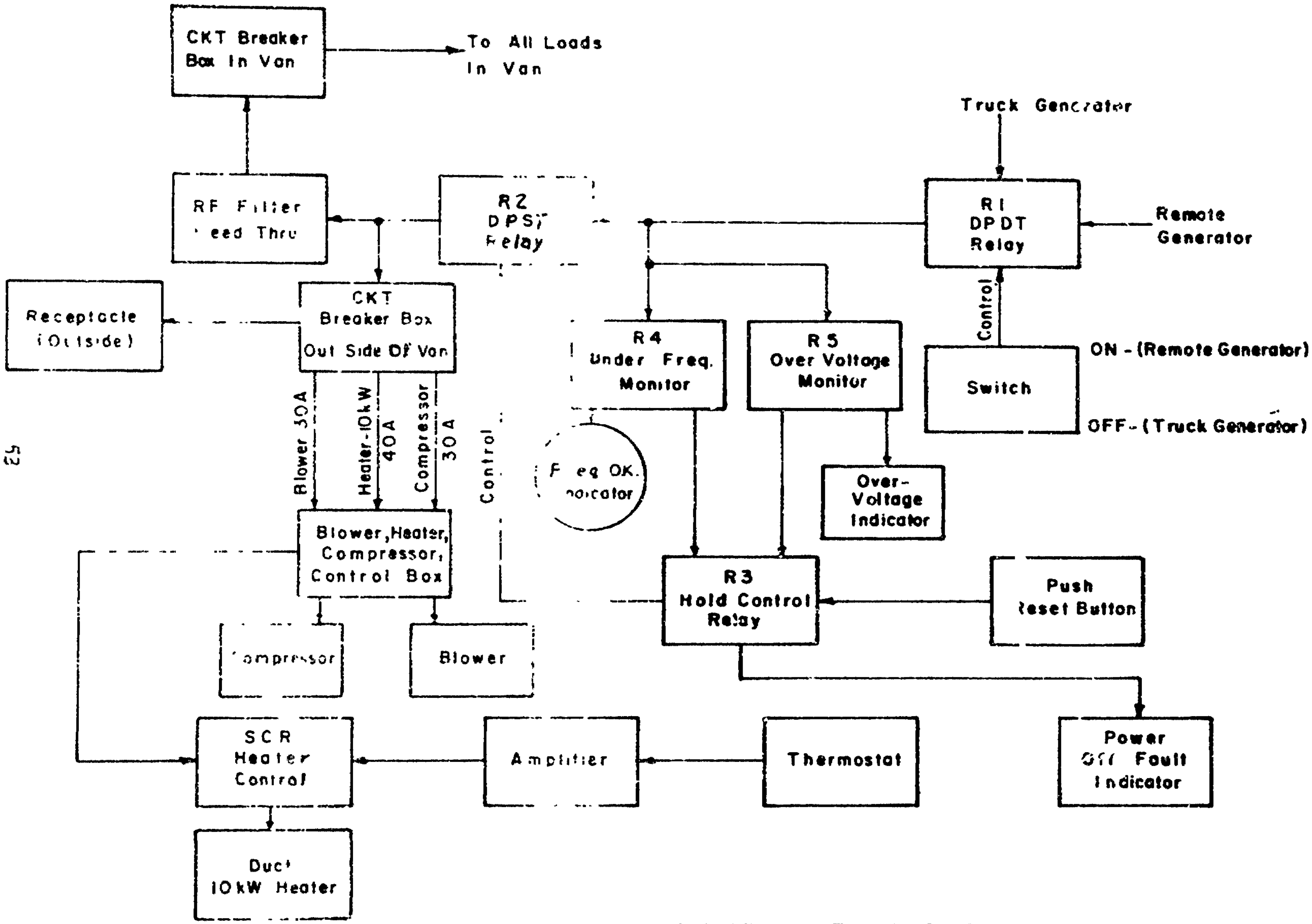

Fig. 27 BLOCK DIAGRAM OF POWER SYSTEM

3.7 Data Recording System (Fig. 12)

Pre-punched program tapes originally enter the CPU through the Interface Unit. Test data from the receiver are modified in the Boxcar Unit and fed through the Interface Unit to the CPU. The CPU, when commanded, performs the data acquisition, records it on the Tape Transport, and causes the Teletype Unit to type out test results.

4. OPERATING INSTRUCTIONS

4.1 Primary Power

Select primary power. This can be the furnished diesel generator; an external 60 Hz, 120/240 VAC single-phase diesel generator; an external 60 Hz, 120 VAC, three-phase generator; or a commercial power line having the characteristics of any of these sources.

Whichever source is selected, it should be capable of providing at least 15 kW total power. If a three-phase, 120 VAC source is selected, only two phases will be utilized. Therefore, each phase should be rated at least 7.5 kW.

Gasoline-powered generators should not be used because they create electrical interference (spark plug noise).

4.1.1 System Generator Connections

The system generator mounted on the vehicle has the necessary connections built in, both electrical and fuel. Diesel fuel is supplied from the two 25-gallon saddle tanks mounted on the truck chassis. Fuel valves are provided so that a larger, external fuel tank may be used if desired.

4.1.2 External Three-Phase Generator Connections

Using an external three-phase generator, connect the neutral conductor of the system power cable to the neutral terminal of the generator. The other two conductors of the cable are connected to any two of the three-phase output terminals.

At the vehicle, the electrical loads are shared between the two selected phases. The air-conditioning system

is connected (within the vehicle) across the two phases (phase-to-phase) so that it obtains approximately 208 VAC for its operation. The system is designed to operate with nominal input voltage between 208 and 240 volts.

4.1.3 External 120/240 VAC Connections

Connect the neutral conductor of the power cable to the neutral terminal of the source. The other two conductors of the cable are connected to the two "hot" outputs of the source (each 120 VAC to common, 240 VAC between the "hot" outputs).

4.1.4 Energizing the Van

4.1.4.1 Start the selected power source.

4.1.4.2 Using switch on power source, connect output of source to system power cable.

4.1.4.3 At the external switch box (Figure 3) throw remote line toggle switch to "on" position if remote power has been selected. When using the system generator, this switch should be in the "off" position. The auxiliary AC line indicator will light if remote power has been selected.

4.1.4.4 The FREQUENCY OK indicator will light when the frequency of the power source is within limits.

4.1.4.5 The POWER OFF fault indicator will light whenever power is applied to the external switch box. Momentarily pushing the RESET button will cause this light to extinguish and attain its normal un-illuminated condition.

4.1.4.6 At the external switch box the blower, heater and compressor are turned on.

4.1.4.7 After entering the vehicle, all switches in the main power switch box (Figure 5) are thrown to the "on"

position. This turns on the interior lights and provides primary power to internal equipment, including the transmitter and equipment racks.

4.1.4.8 The wall-mounted thermostat should be set to the desired temperature (usually 70-80°F). Temporarily setting the thermostat to a higher temperature than ultimately desired will not produce a faster warm up.

4.1.4.9 After power has been turned on within the vehicle, various auxiliary instruments located in the instrumentation rack should be turned on.

4.2 Initial Set-Up Procedure

1. Select transmitter to be used. No. 1 is the left-hand unit while No. 2 is the right-hand unit.

2. Connect selected transmitter's output to correct transmitter port (double-ended type "N" feed-thru connector) located on the van wall near the window.

3. Check that the selected port is correct and that the 7/8 inch diameter Heliax transmission line on the external end of it connects to the desired transmitting antenna (tower or ground).

4. Install the appropriate low-pass filter in the transmitter output line. Physically, it should be located at the transmitter front panel. Check that, after installation, the door will close. Table I indicates the correct filter.

Transmitting Frequency, MHz	Filter Type
230.0	TLC 430-7EE1
307.7	TLC 430-7EE1
436.1	TLC 750-7EE1
550.9	TLC 750-7EE1
737.0	TLC 750-7EE1

TABLE I SELECTING TRANSMITTING FILTERS

5. Install a receiving bandpass filter at the input end of the pre-amplifier box (between the box and the antenna transmission line) which is appropriate for the frequency being received, as indicated in Table II.

Receiving Frequency, MHz	Filter Type
690.0	TBC 690-78-9EE1
923.1	FBC/20-923/50-7/50-1A/1A
1308.3	TBA 1305-230-6EE
1652.7	FBT/20-1652/80-8/50-1A/1A
2211.0	FBT/5-2211/130-8/50-1A/1A

TABLE II SELECTING RECEIVING FILTERS

6. Remove metal pre-amplifier box cover, set switches appropriate to the desired receiving frequency and replace cover.

7. Select proper receiving antenna in accordance with Table III and connect to filter at pre-amplifier box.

Receiving Frequency, MHz	Tower Receiving Antenna For Moving Targets	Tower Receiving Antenna For Stationary Targets	Ground Receiving Antenna
690.0	Small LPA	Small LPA	Small LPA
923.1	Small LPA	Small LPA	Small LPA
1308.3	Small LPA	Dish	Dish
1652.7	Small LPA	Dish	Dish
2211.0	Small LPA	Dish	Dish

TABLE III SELECTING RECEIVING ANTENNAS

8. When using the tower antennas, check that both transmitting and receiving units have the desired polarization (horizontal or vertical). Ground antennas are fixed-polarized horizontal.

9. Insure that no target is in the target area until so indicated.

4.3 Transmitter

1. Place transmitter control in REMOTE position.

2. Set PRF (Pulse Recurrence Frequency) to 1kHz.

3. Tune transmitter into dummy load. Set RF MONITOR switch to unused transmitter to zero power meter and to in-use transmitter to measure power output. Refer to available power level vs. frequency chart.

4. Adjust output pulse width to one microsecond, using the oscilloscope.

5. Turn RF DRIVE control on RF Exciter to zero.

6. Connect transmitter to antenna.

7. Turn up RF DRIVE control. Re-check output power level and pulse width.

4.4 Receiving System

1. Select proper tuning head.

2. Set bandwidth to 1 MHz.

3. Adjust video gain fully clockwise.

4. Adjust the IF gain knob to a position which corresponds to the approximate center of the appropriate IF gain vs. K factor chart.

5. Set delay and amount of attenuation in the reference line as indicated by the wall chart.

6. Set the Weinschel attenuator for maximum attenuation (120dB).

7. Set the "Tune-Calibrate/Receive" switch on the boxcar unit to "Tune".

8. Set the Weinschel attenuator to approximately 50 dB. Do not use less than 30 dB attenuation as so doing might damage the receiver.

9. Connect oscilloscope to the receiver's video output and adjust tuner for a DC peak (maximum amplitude of the horizontal trace).

10. Re-adjust both the tuner and the Weinschel attenuator to provide zero output on one boxcar channel, as measured on the digital volt meter (DVM) and about five to seven volts on the other channel. The phase shifter

may need adjustment to obtain the zero reading.

11. Adjust the FINE TUNING control on the tuner to peak the output on the maximum channel.

12. Set "Tune-Calibrate/Receive switch on the boxcar unit to "Calibrate/Receive".

13. Set the switches on the attenuator control box for maximum attenuation (all three blue lights are illuminated) and zero both boxcar outputs.

14. Re-set these switches for zero attenuation (all three lights are not illuminated) and check the DVM readings (check both channels) for possible residual signal. A reading of a few millivolts is acceptable. A slightly higher residual level (20 or 40 millivolts) can sometimes be balanced out by adjusting the phase shifter. A significant residual level necessitates halting of the procedure until it is corrected (See Appendix C).

15. Assuming that the residual level is negligible, adjust the boxcar range gates. This is usually performed by placing a test target (diode/dipole combination) at the target location and adjusting the range gates (one channel at a time) for maximum indications on the DVM. The calibration diodes should not be used as test targets since they are not located at the target areas. Remove the test diode.

16. An alternate technique for adjusting the range gates utilizes the targets themselves. A temporary cable is teed from a boxcar input and the phase shifter adjusted for a maximum video signal on the oscilloscope. The appropriate range gate is then adjusted so that the start of the pulse rides on top of the signal (Fig. 28). Repeat for the other channel. Remove the tees from the boxcar inputs.

FIG. 28 CORRECT POSITIONING OF PULSE

17. Perform system sensitivity test by switching in the calibration diodes (located near the transmitting antennas) and monitoring receiver video output on the oscilloscope and boxcar outputs with the DVM. When using an actual or simulated target, the oscilloscope wave-shape is typically as shown in Figure 29. Signal levels should approximate those indicated on a wall chart. If not, halt the procedure until the fault has been remedied.

18. If system sensitivity is acceptable, switch out the calibration diodes. The system is now ready to be used with actual targets.

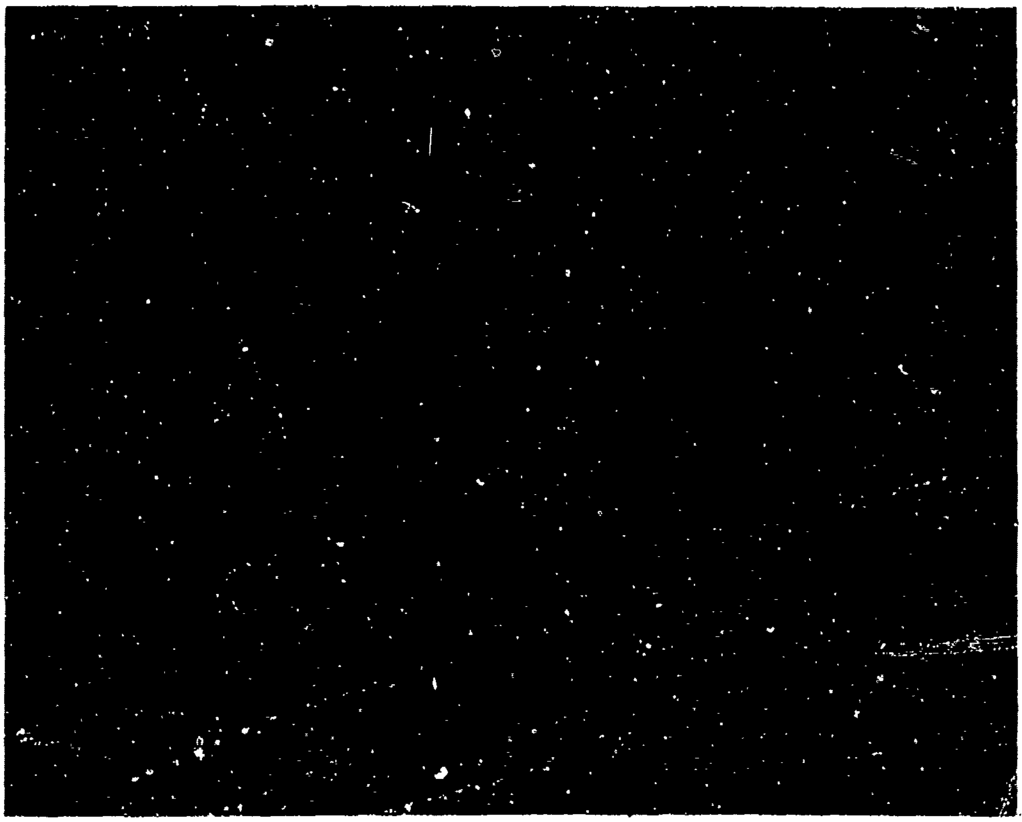

Fig. 29 TYPICAL RECEIVER WAVESHAPE, USING AN ACTUAL OR SIMULATED TARGET

19. Select appropriate test sequence to be followed from Appendix ' . Use appropriate information format as described in Appendix D.

4.5 Data System Operating Procedure

Follow instructions in Table IV, using Table V to load the program. Use commands listed in Table VI. Trailer format information can be found in Appendix D.

4.6 Shutting Down

The transmitter is normally turned off first, then the receiver and rack-mounted instrumentation, then all the switches in the main power switch box are turned off.

After this, at the external switch box, the blower, heater and compressor switches are turned off. After this, the remote line toggle switch is turned to the "off" position. The main power source may then be turned off.

4.7 High Ambient Temperatures

No special instructions are required for operation at high ambient temperatures.

4.8 Low Ambient Temperatures

No special instructions are required for operation at low ambient temperatures. However, special techniques may be required to start the diesel generators. Normally, one or two sprays from a spray can of ether can be directed at the unit's air cleaner from a distance of about two feet while the unit is being electrically cranked. This usually insures cold-weather starting.

TABLE IV - SYSTEM OPERATING PROCEDURE

ACTION	COMMENTS
1. Perform routine maintenance on tape drive.	1. A well-maintained tape drive is imperative for an operating system.
2. Turn on power to CPU interface, tape drive and teletype.	
3. Turn teletype to "On Line".	
4. Load tape onto tape drive, as illustrated in the manual, with a file protect ring.	Wind 3-4 turns of tape on the take-up reel and make sure the vacuum chamber is <u>empty</u> of tape.
5. Depress Load.	Tape should be sucked into the chamber advance until the load point marker is at the detector and stop. The indicators Power, On Line, Load and Reset should be illuminated. The File Protect indicator should be off. If not, remove tape and place file protect ring on.
6. Set CPU Switches to 2254, (EXRCS), depress Reset and Start.	
7. Type BT ⤶ Note! THIS COMMAND MUST BE USED TO WRITE TAPE.	Tape should advance ~ 2-1/2" and stop.
8. To check receiver noise output, type NT ⤶	After a 20 second delay, the teletype will respond with max, min & average absolute values of the channel outputs.
9. To check the receiver output with the Xmtr on, type ST ⤶	Same as 8.

TABLE IV - SYSTEM OPERATING PROCEDURE (Cont.d)

ACTION	COMMENTS
	These tests can be repeated with the receiver gain changed until the signal level is satisfactory.
10. Type IT ↲	Response: Run Number 3D = XXX The trailer data can be accepted or modified by the commands outlined in the command summary sheet. NOTE! If the value after the = sign is to be changed, a number of characters and/or blanks equal to the number within the brackets must be typed.
11. Type RL ↲ for 512 records.	The above number of records will be written on tape and the Pmax, Pmin, # parity errors and signal parameters will be typed out.
12. If the data summary indicates the records are not acceptable, then Type BS ↲	The tape drive should back space the number of records written.
13. If the data summary indicates the records are acceptable, a free text record may be entered if desired. If so, type FT ↲	NOTE! A free text record should <u>not</u> be written until the data summary is examined, since the BS command will not space the additional written record.

TABLE IV - SYSTEM OPERATING PROCEDURE (Cont.d)

ACTION	COMMENTS
14. After every accepted RL run and every group of RS runs, an end-of-file record must be written.	The tape drive will write an end-of-file record and stop.
Type EF ↲ .	
	After nine RL runs or an equivalent number of RS runs, the teletype will respond with a replace tape command.
15. Type EF ↲ EF ↲ WD ↲	The tape drive will rewind to the load point and stop.
16. Depress "Power" switch on tape drive and replace tape.	NOTE! Four end-of-file (EF) records must be written at the end of the last record on a reel.

If the system does not respond to the commands outlined above or those of the command summary, refer to the trouble-shooting chart of Table A-4.

TABLE V - PROGRAM LOAD PROCEDURE

PROGRAM	ACTION	SYSTEM RESPONSE	POSSIBLE PROBLEMS
Binary Block Loader	1. Set CPU switches to *X17770.	1. Program loaded into computer	NONE
	2. Place program in reader.	2. Program not loaded.	1. Check bootstrap loader.
	3. Depress CPU switches Reset, Start		2. Change bootstrap loader and attempt a load via the teletype reader.
			3. If program loads via the teletype, check high speed reader/interface.
Bootstrap Loader	1. Set CPU switches 17757.	Address Indicator 17757.	If instruction does not agree with indicator, set value in switches and depress deposit.
	2. Depress Examine	Instruction Indicator 126440	
	Continue the above procedure to check and/or load the 13 instructions of the bootstrap loader on the programming card.		
Binary Program	1. Set CPU switches to *X17777.	1. Program should load into CPU.	If no load, first load Binary Block Loader, then Bootstrap Loader.
	2. Depress CPU switches Reset, Start		

*X = 0 for teletype reader
X = 1 for paper tape reader

TABLE VI - COMMAND SUMMARY

EXEC COMMANDS

INPUT	FUNCTION	SYSTEM RESPONSE
NT ↲ *	Noise Test - Check receiver noise level with transmitter off	Monitors the receiver output for 10 sec. and prints the channel max, min, and average absolute relative output level.
ST ↲	Saturation Test - Check receiver output level	Monitors the receiver outputs for 10 sec. and prints the channel max, min, average absolute, relative output levels, and flags saturation and max and min relative output power. (P_{max} and P_{min})
RS ↲	Run Small writes 50 records on tape	Writes 50 records on tape "10 seconds" and prints number of parity errors in addition to that of the saturation test.
RL ↲	Run Large writes 512 records on tape	Writes 512 records on tape and responds as Run Small.
BS ↲	Back Space	Back spaces the number of data records written prior to this command.
WD ↲	Rewind Tape	Rewinds tape to start of reel and initializes the full reel count.
EF ↲	writes End of File	Writes an end of file record on tape; must be written between Large Run experiments and between groups of Small Run experiments.
BT ↲	writes BOT gap	Erases five inches of tape at the beginning of the reel.
IT ↲	Input Trailer	Transfers control from the Exec program to Input Trailer Program to allow changing the trailer data.

* "Return" key.

TABLE VI - COMMAND SUMMARY (Cont'd)

	INPUT	FUNCTION	SYSTEM RESPONSE
	FT ↲	Free Text	Transfers control from the Exec program to Free Text program to allow writing a free text record.
TRAILER COMMANDS	↲	Accepts previous or modified character string concerning a particular test parameter.	Couples the succeeding trailer parameter with its descriptive format to be typed out.
	cntl B	Enables the last character string typed to be modified.	System types \, the character string typed will replace those beginning with the first character after =.
	cntl A	Enables the start over of the input trailer routine.	Types the initial trailer parameter with its format to be typed out.
	cntl E	Allows the remaining trailer data to be accepted and stored in the data buffers.	Stores the data in the data buffers.
FREE TEXT COMMANDS	cntl A	Rub Out Last Character	← character echo for each rubout.
		The following command inputs function only at the beginning of a line.	
	cntl B	Rubout Last Line	\LAST
	cntl C	Rubout Text	\TEXT
	cntl K	List Last Line	Last line typed out.
	cntl L	List Text	Entire text typed out.
	cntl E	Record Text	TEXT RECORDED.

5. PERFORMANCE DATA

5.1 Transmitter

Basic transmitter performance is described in the Transmitter Operation and Instruction Manual (Volume I). However, use of the transmitter in the VP METRRA system results in some specialized power supply meter readings. Typical power supply readings for a condition of 5 kW pulse power and a 1% duty cycle are shown below in Table VII.

Table VII

TYPICAL POWER SUPPLY METER READINGS

Power Supply Output Voltage (DC)	Power Supply Output Current (DC Milliamperes)
1000	5
1500	10
2000	20

Typical 5 kW pulse output waveshapes are shown in Figures 30 and 31.

5.2 Receiver Pre-Amplifiers

Typical performance of the three pre-amplifiers is shown in Figures 32 to 34.

5.3 Transmitting Low-Pass Filters

Filter Type TLC430-7EE1 has a response as shown in Figure 35.

Filter Type TLC750-7EE1 has a response as shown in Figure 36.

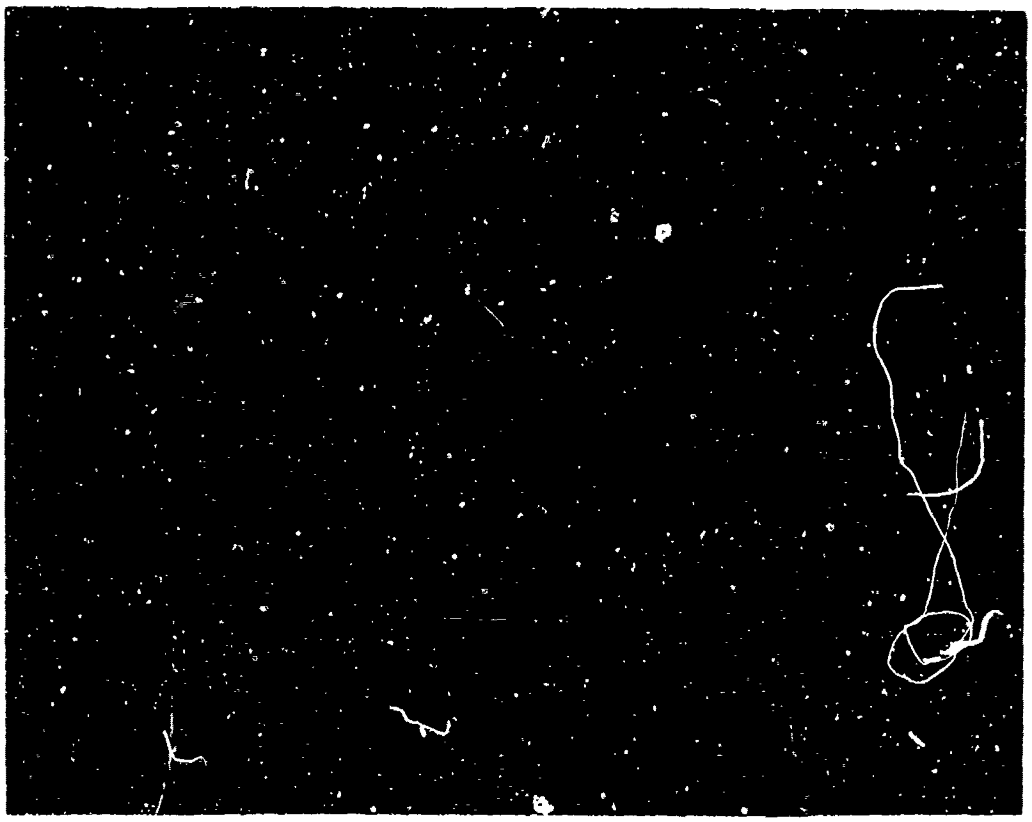

Fig. 30 5 kW POWER OUTPUT INTO DUMMY LOAD AT 230 MHz

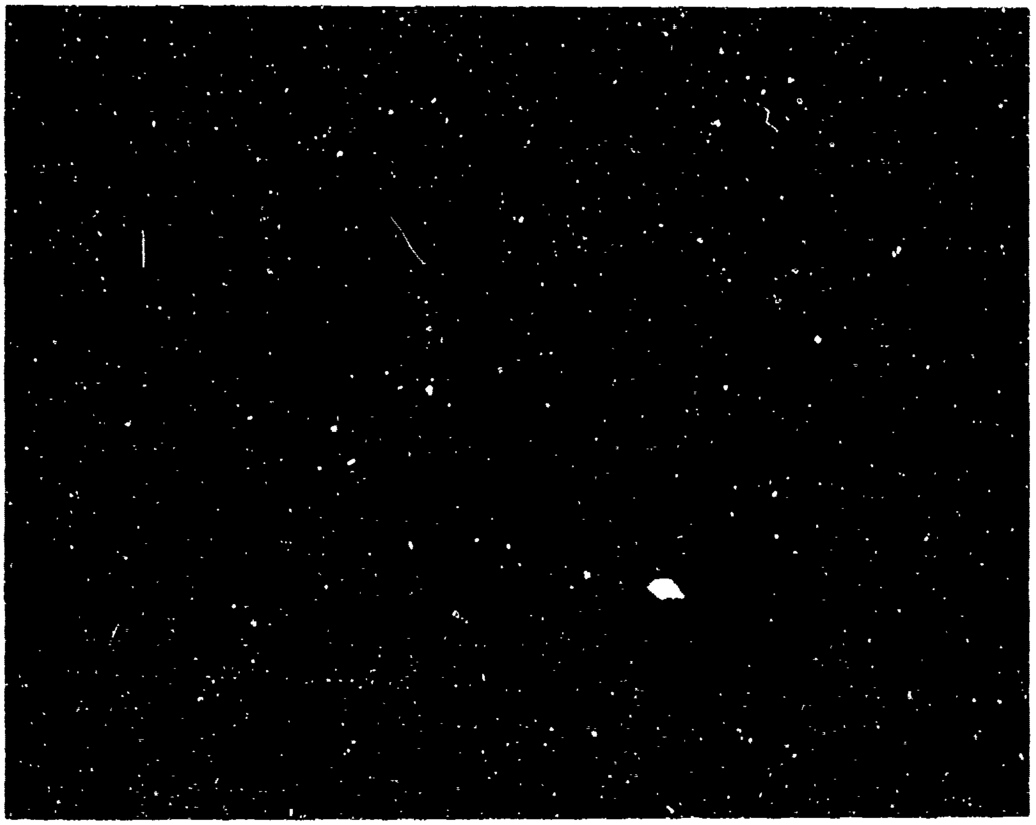

Fig. 31 5 kW POWER OUTPUT INTO TRANSMITTING ANTENNA NO. 4 AT 230 MHz

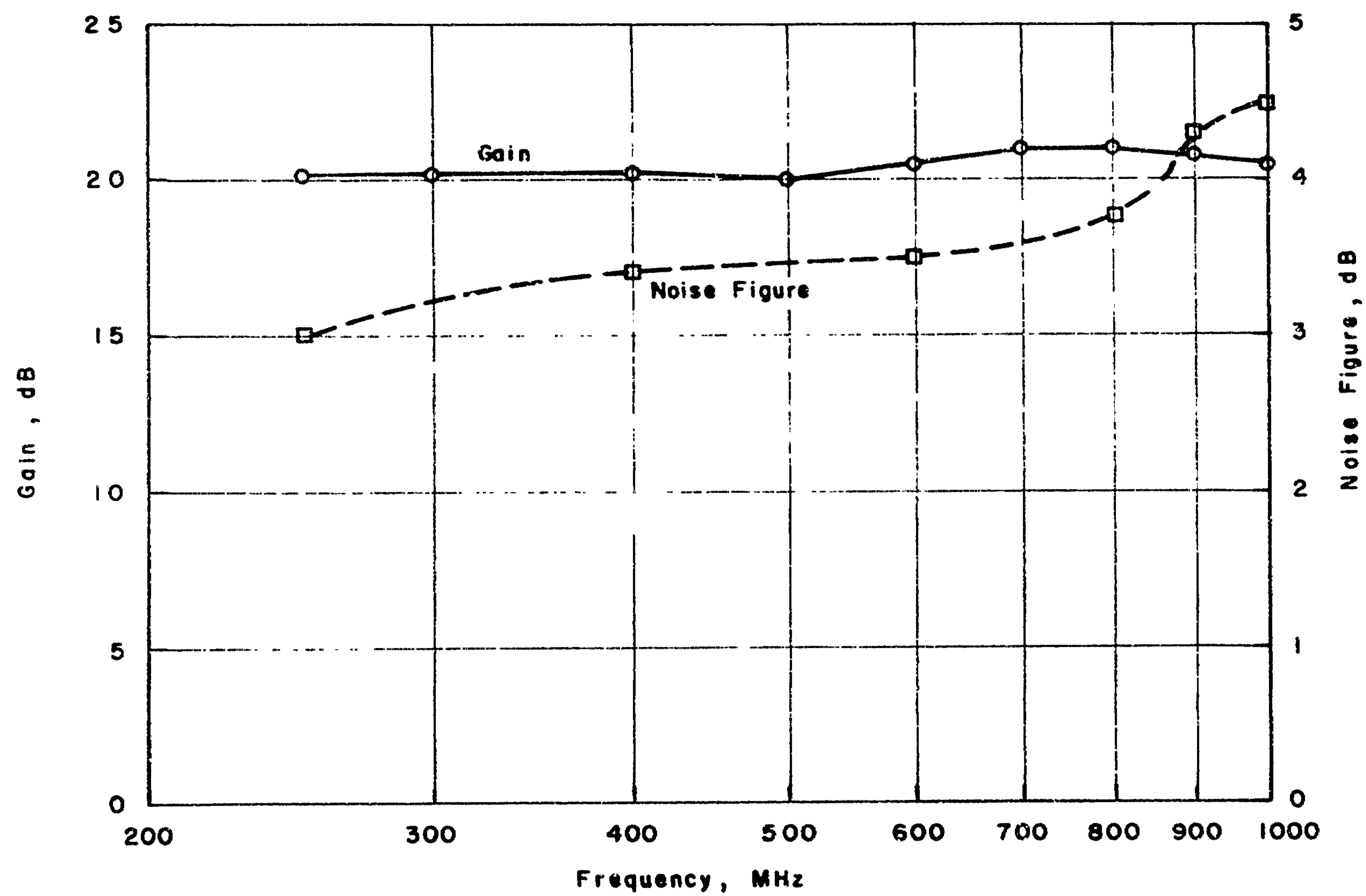

Fig . 32 PERFORMANCE OF 250-1000 MHz PRE-AMPLIFIER

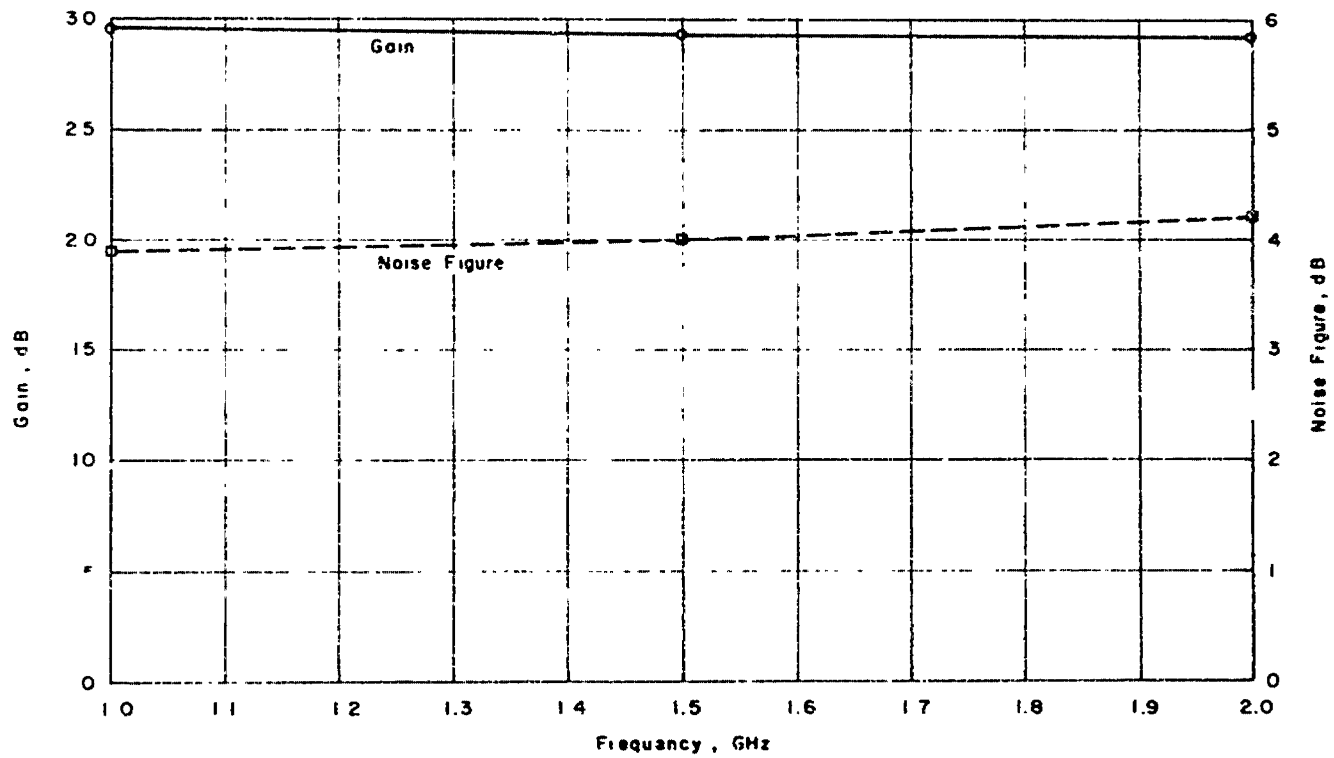

Fig. 33 PERFORMANCE OF 1-2 GHz PRE-AMPLIFIER

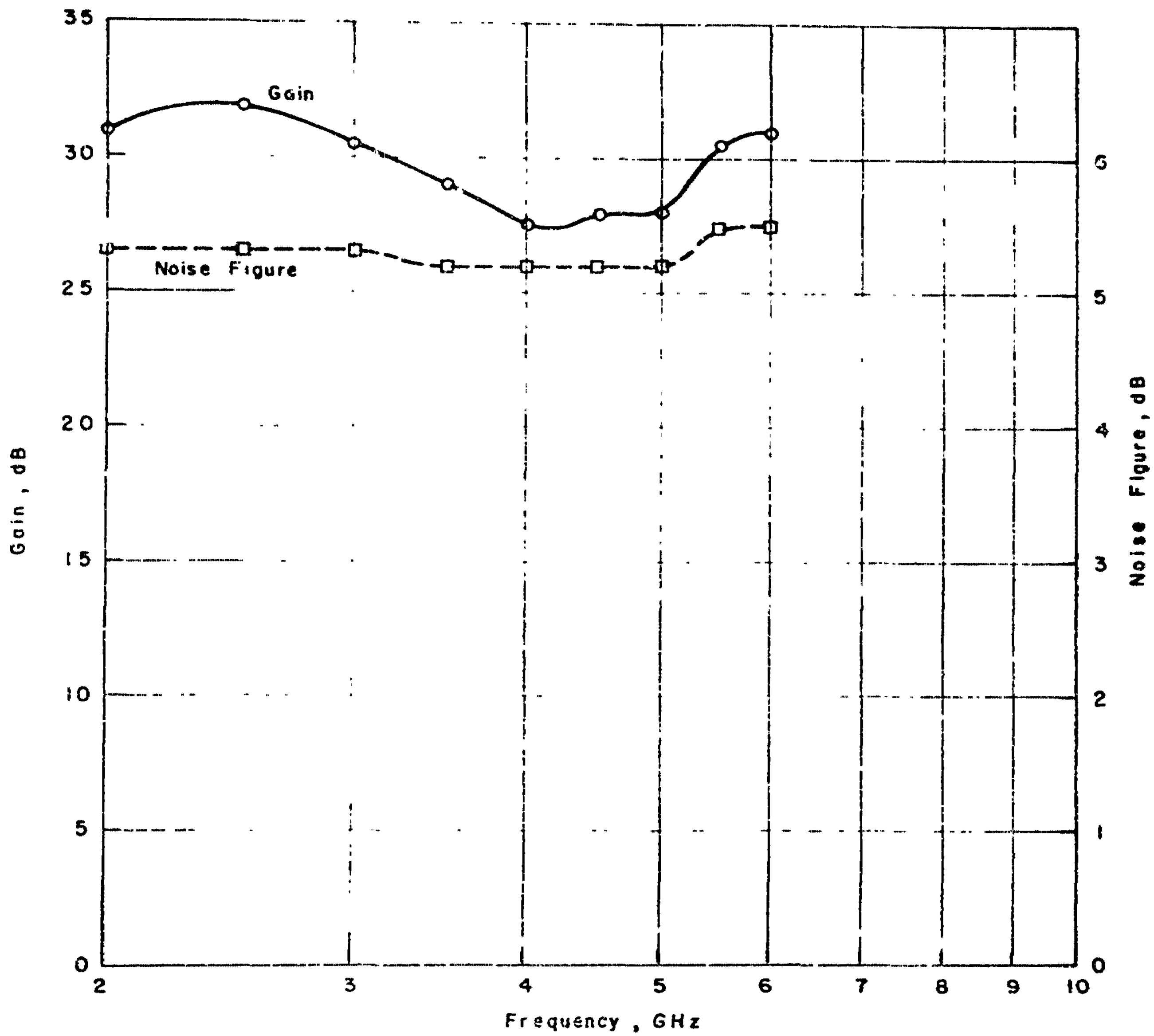

Fig. 34 PERFORMANCE OF 2-6 GHz PRE - AMPLIFIER

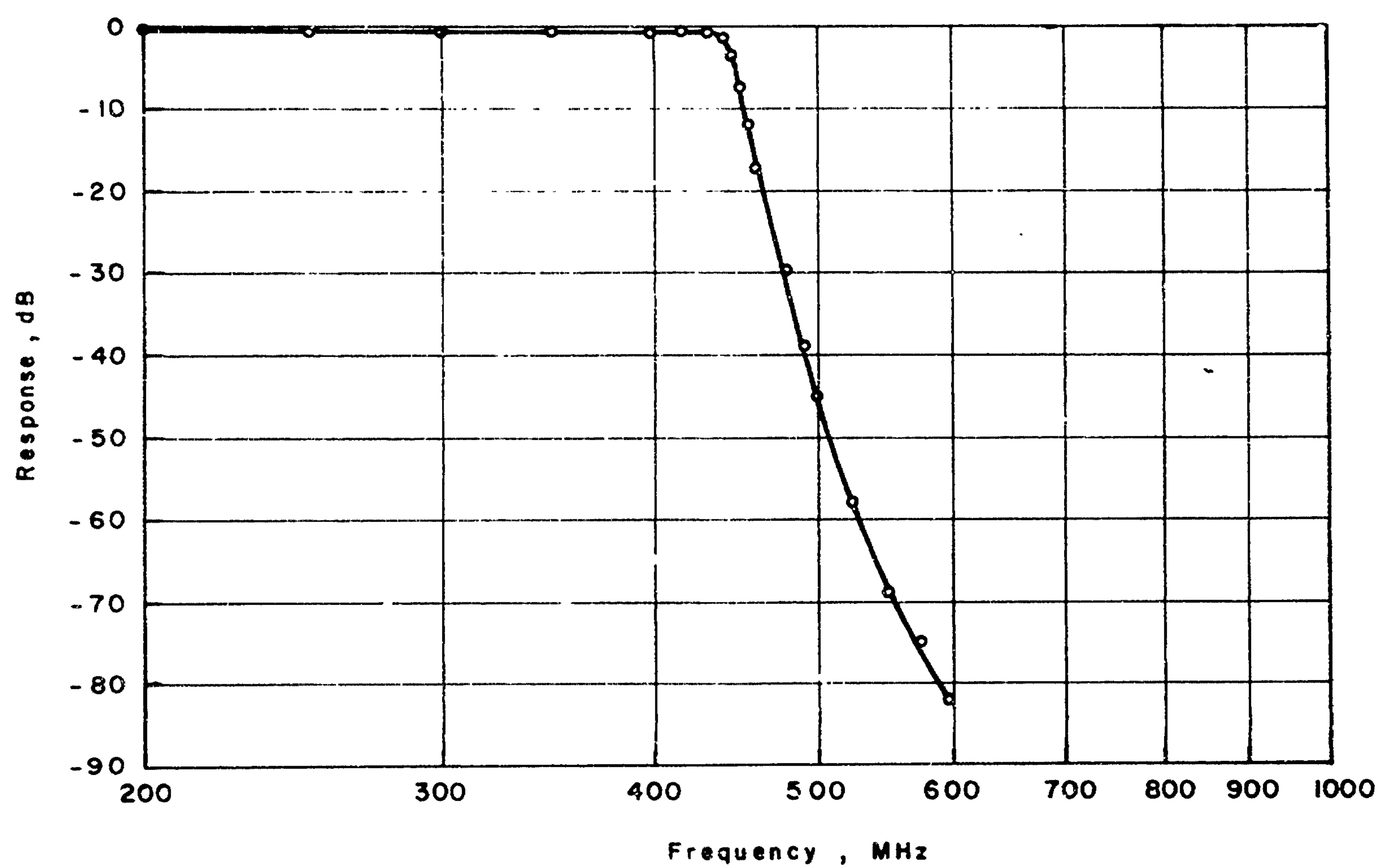

Fig. 35 RESPONSE OF TLC 430 - 7EE1 FILTER

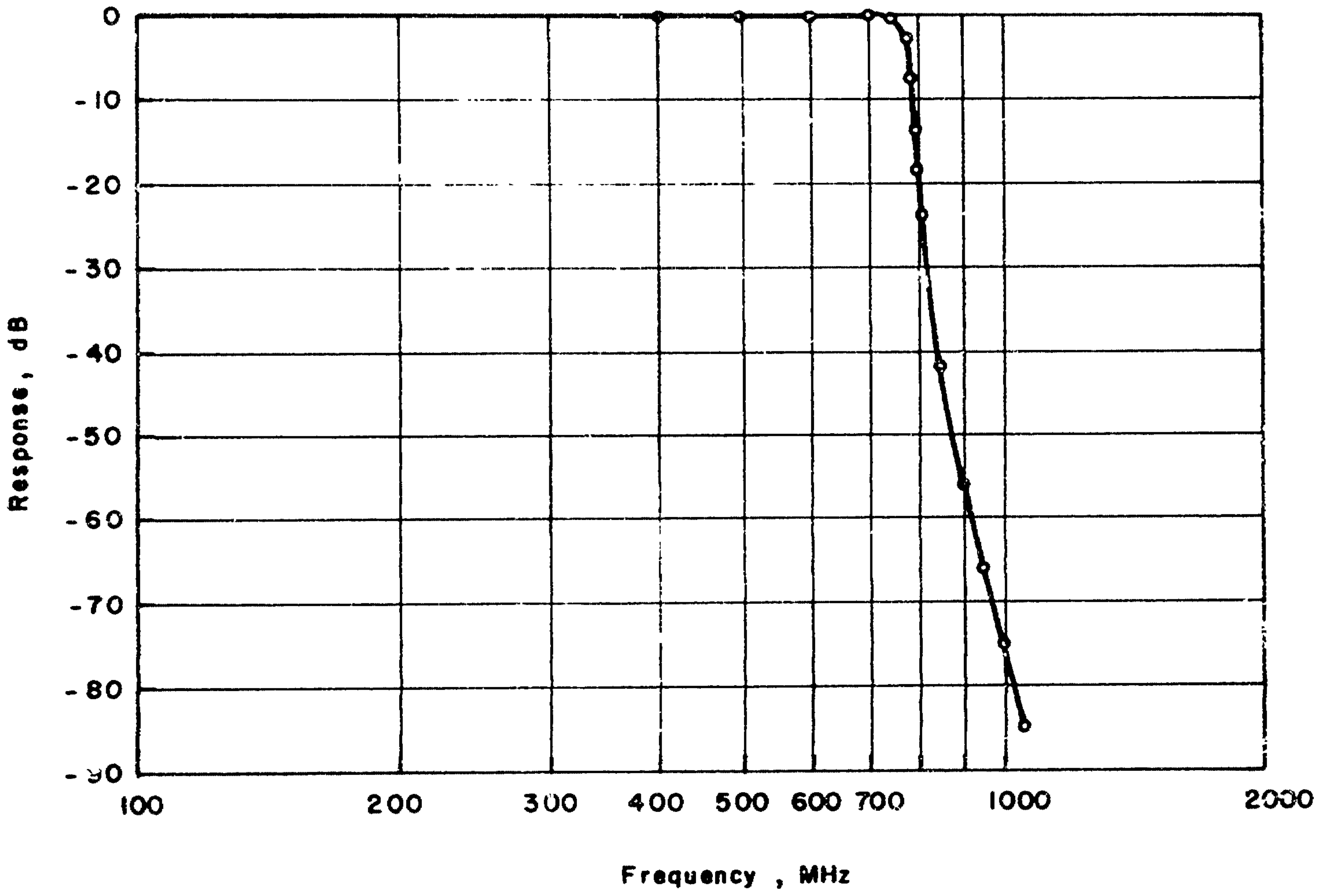

Fig. 36 RESPONSE OF TLC 750-7EE1 FILTER

5.4 Receiving Bandpass Filters

Receiving bandpass filters have a maximum insertion loss of 1 dB in the pass band. Stop band attenuations are as listed below in Table VIII.

Table VIII

RECEIVING FILTER ATTENUATIONS

Receiving Center Frequency (MHz)	Minimum 95 dB Out-of-Band Rejection at	Filter Type
690	411 MHz, 551 MHz	TBC690-78-9EE1
923	551 MHz, 737 MHz	FBT/20-923/50-7/50-1A/1A
1308	407 MHz through 463 MHz	TBA1305-230-6EE
1652	986 MHz, 1319 MHz	FBT/20-1652/80-8/50-1A/1A
2211	1319 MHz, 1765 MHz	FBT/5-2211/130-8/50-1A/1A

The unusual frequencies selected for measurement were originally planned as intermodulation frequencies.

5.5 Boxcar Unit

Figure 37 shows a typical response of both boxcar unit channels.

5.6 Receiving System

The receiving system consists of the pre-amplifier box, receiver and boxcar unit, plus the coaxial cable connecting the pre-amplifier box to the receiver.

Sensitivity of the receiving system is a function of the low noise figures of the pre-amplifiers (3.9-5.5 dB)

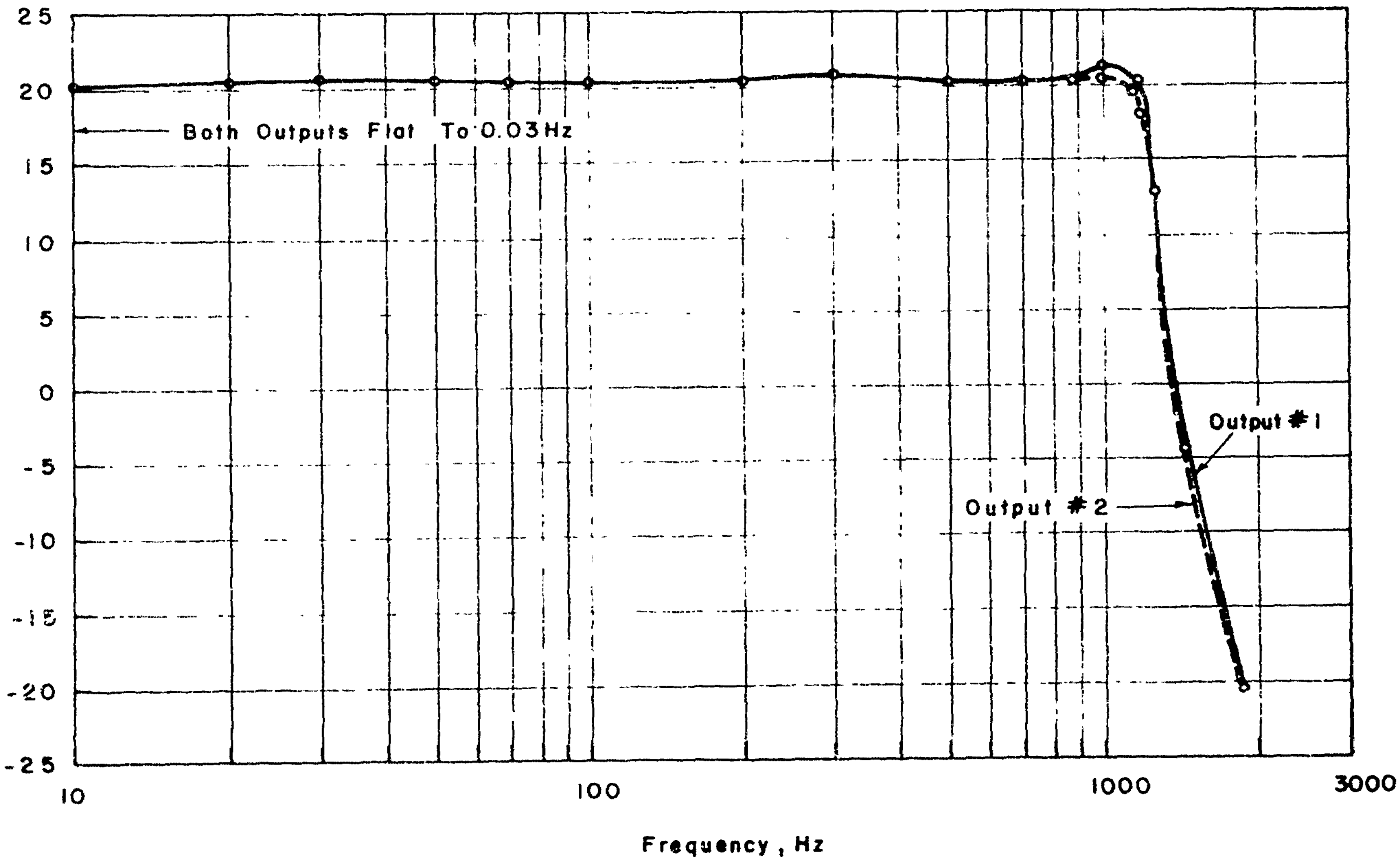

Fig. 37 RESPONSE OF BOXCAR CHANNELS

which overcome the high noise figures of the receiver (12-18 dB). Sensitivity of the system, as measured at the boxcar output, is shown in Table IX.

Table IX

RECEIVING SYSTEM SENSITIVITY
(PRE-AMPLIFIER INPUT)

Receiving Frequency (MHz)	Receiving System Sensitivity (dBm)
690	-115
923	-113.5
1235	-113.5
1650	-115
2211	-113.5

At the sensitivities shown in Table IX, 60 dB dynamic ranges were obtained. Figures 38 and 39 show typical curves.

5.7 Antennas

Figures 40 through 64 show performance characteristics of the VP METRRA antennas. Radiation patterns are not available for other than the APN-109B.

5.8 Overall VP-METRRA System Noise

It is imperative that the system have inherently low noise so that weak signal returns can be evaluated. Both transmitting and receiving systems could conceivably contribute noise.

To evaluate system noise, a fabricated diode mounted in a dipole antenna is used as a test target which provides a constant received signal. The receiver IF gain is

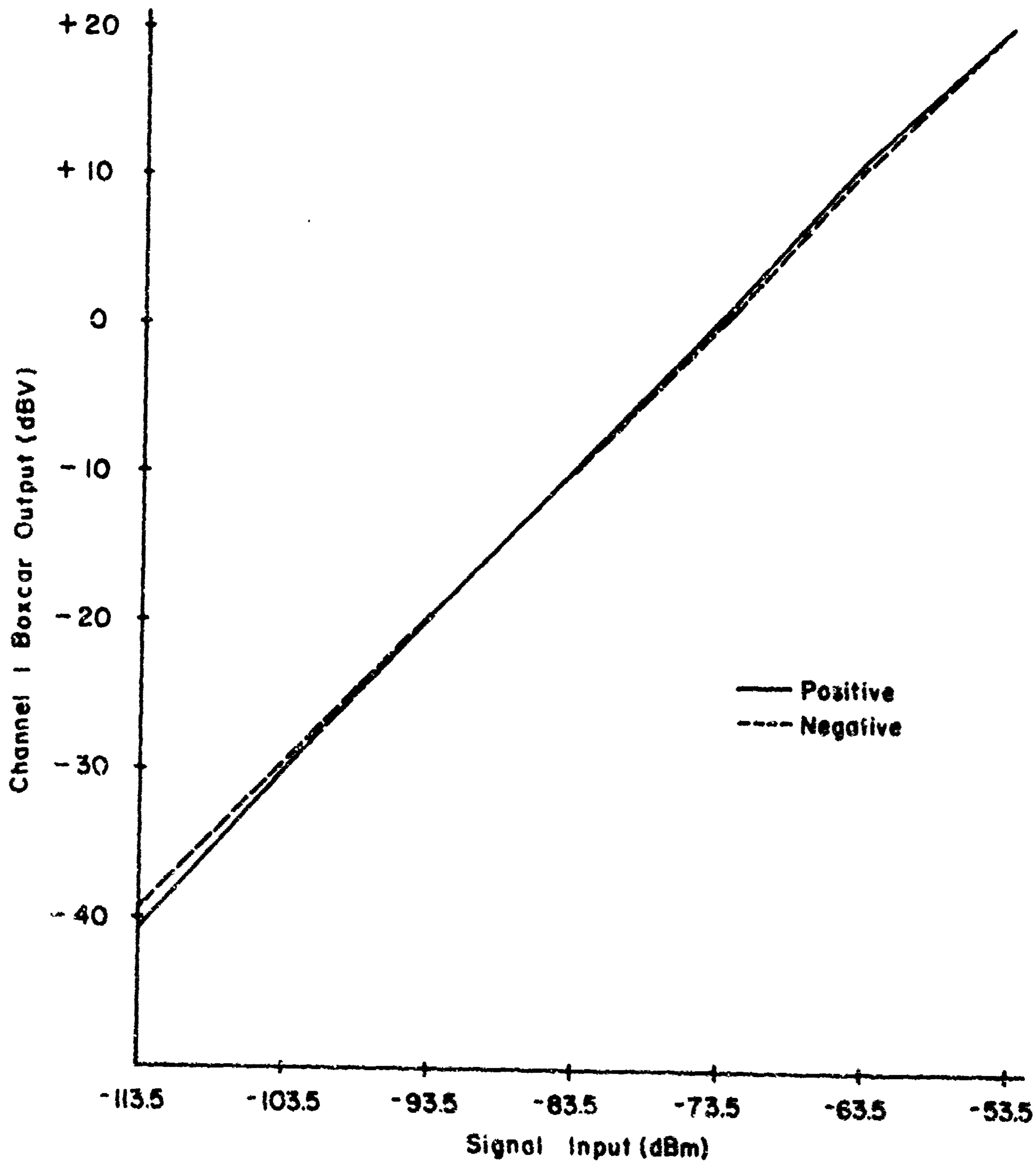

Fig. 38 LINEARITY OF RECEIVER I-CHANNEL AT 923.1 MHz (IF DIAL SET AT 250)

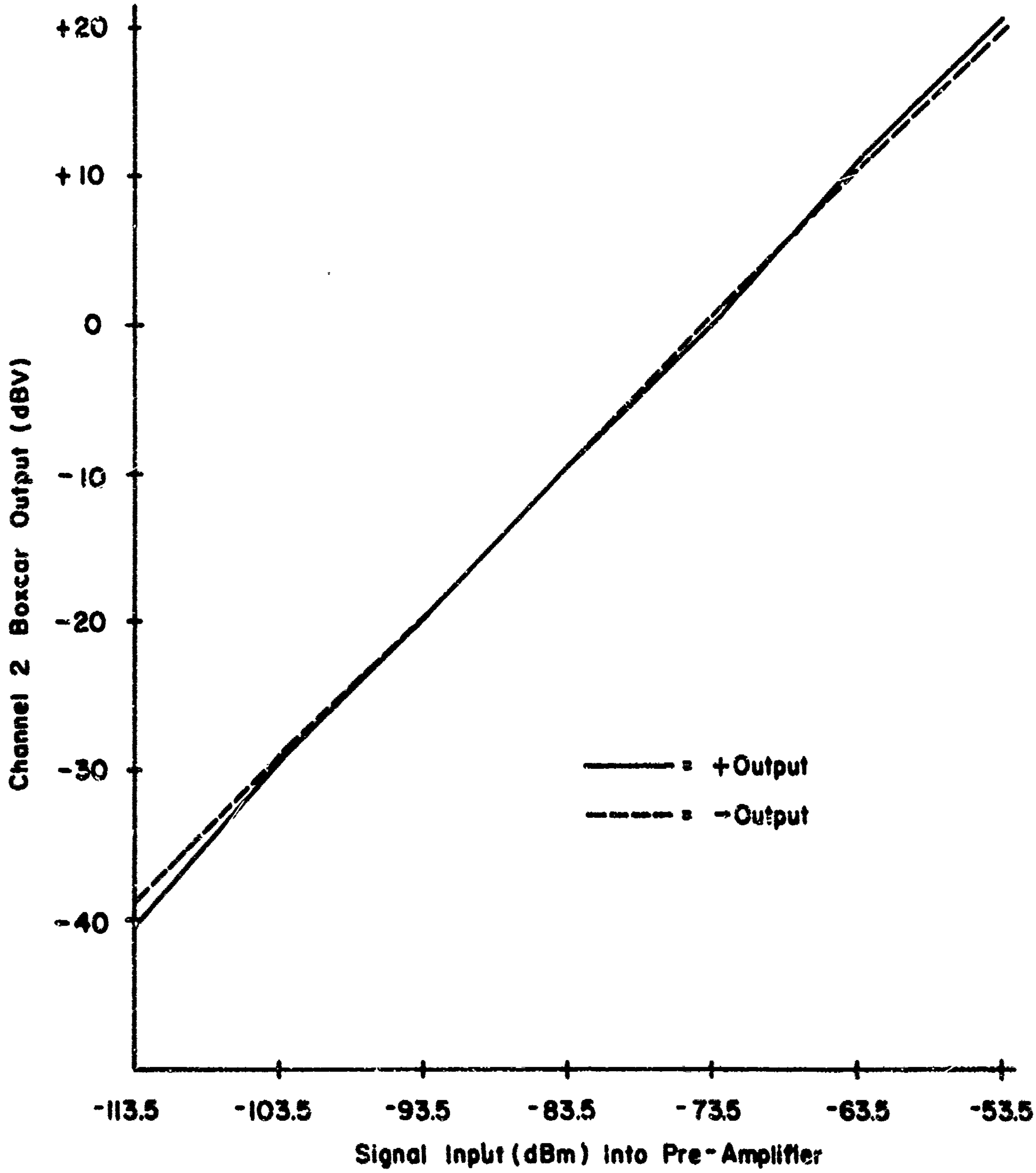

Fig. 39 LINEARITY OF RECEIVER Q-CHANNEL AT 923.1 MHz (IF DIAL SET AT 250)

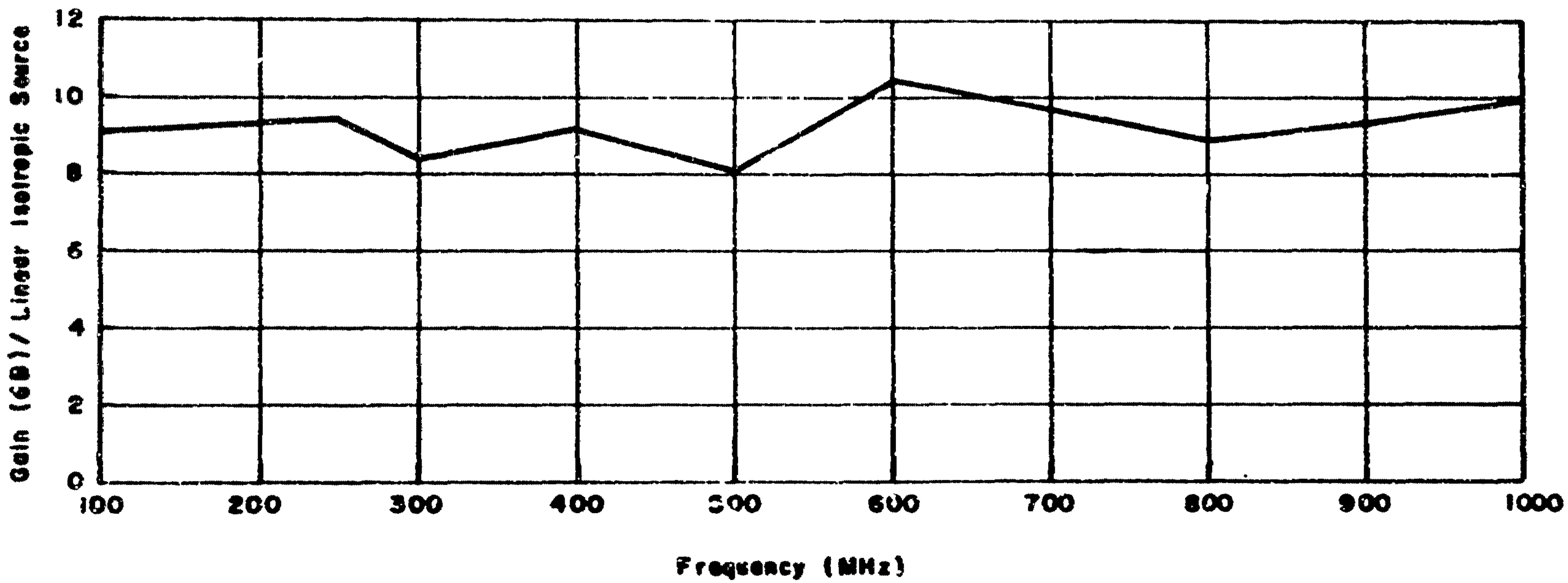

Fig. 40 GAIN OF APN-109B TOWER TRANSMITTING ANTENNA

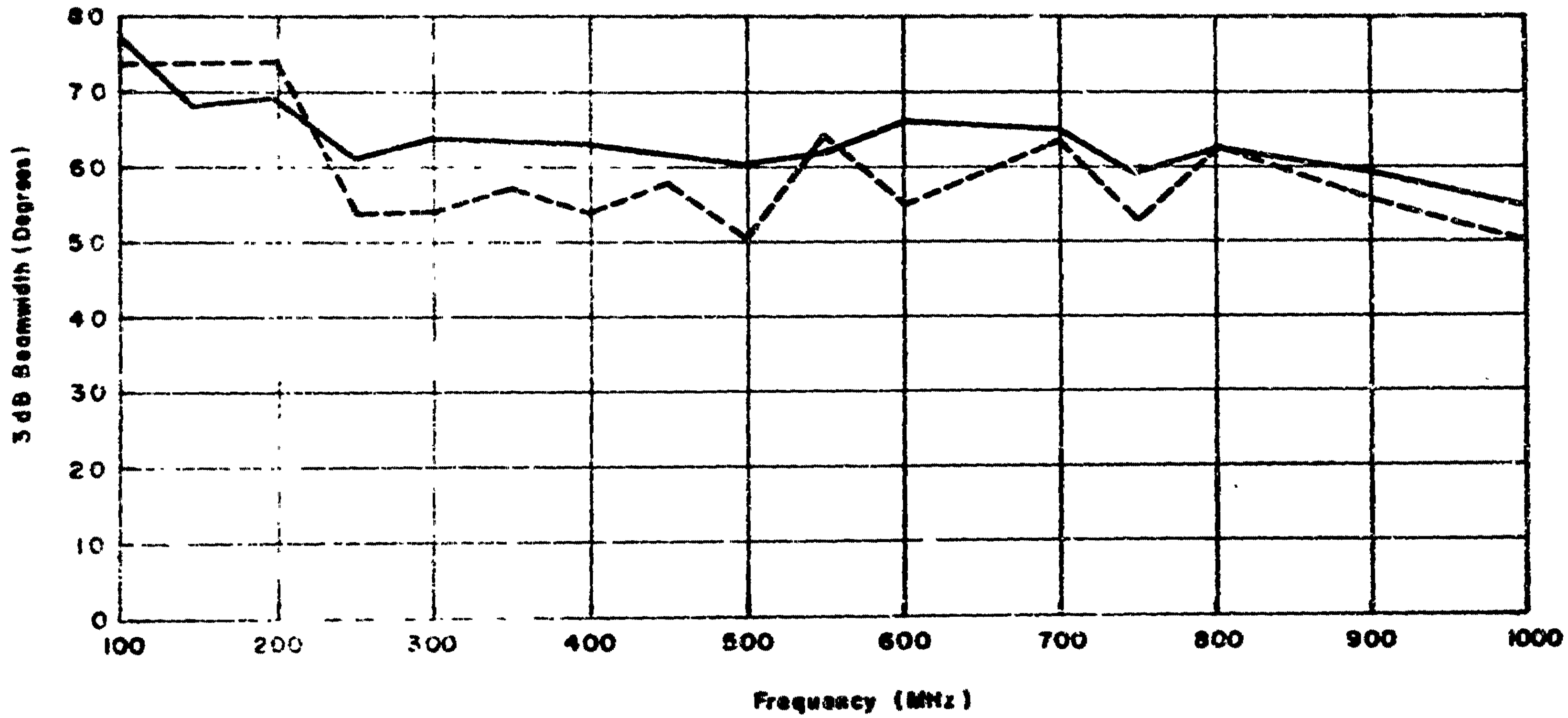

Fig. 41 BEAMWIDTH OF APN-109B TOWER TRANSMITTING ANTENNA

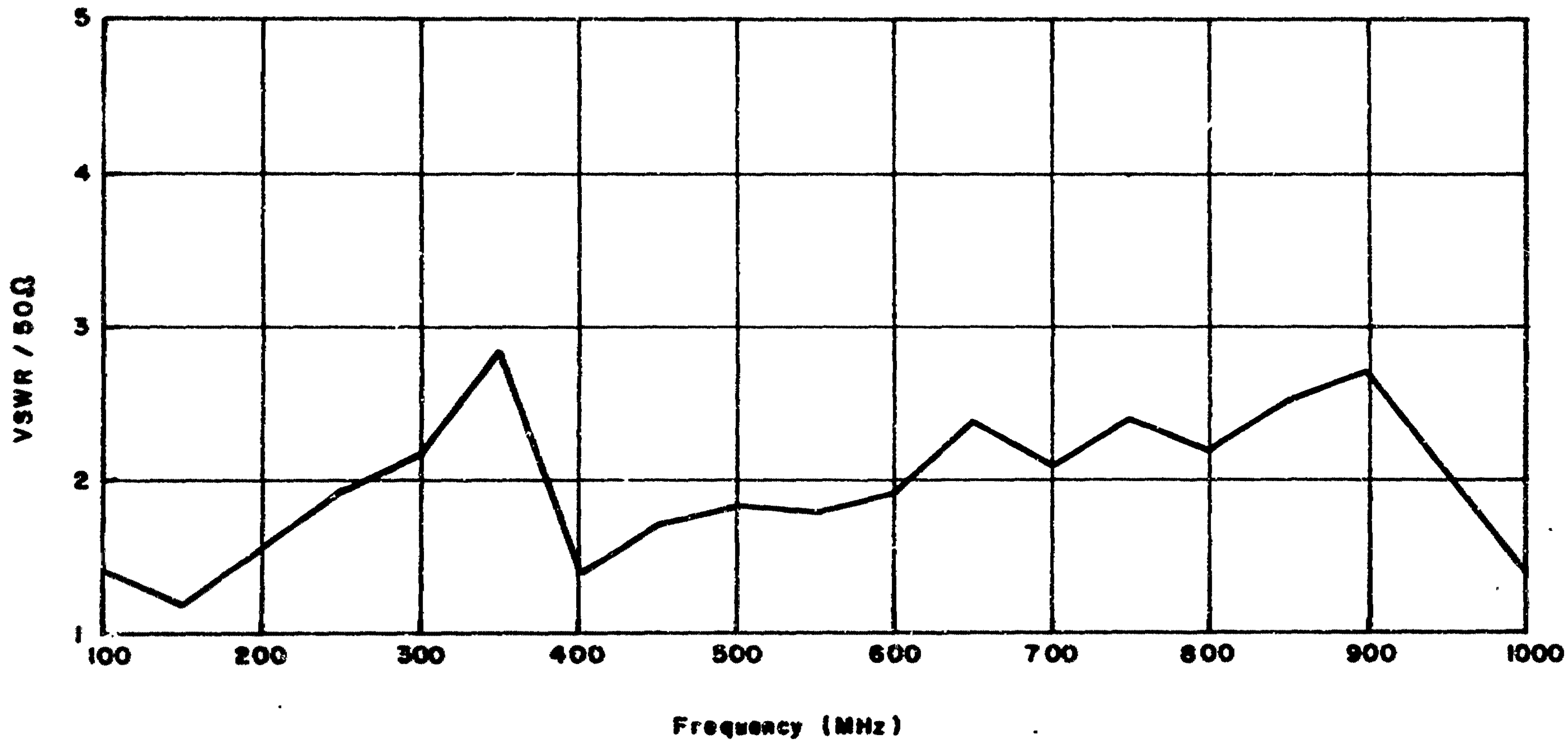

Fig. 42 VSWR OF APN-109B TOWER TRANSMITTING ANTENNA

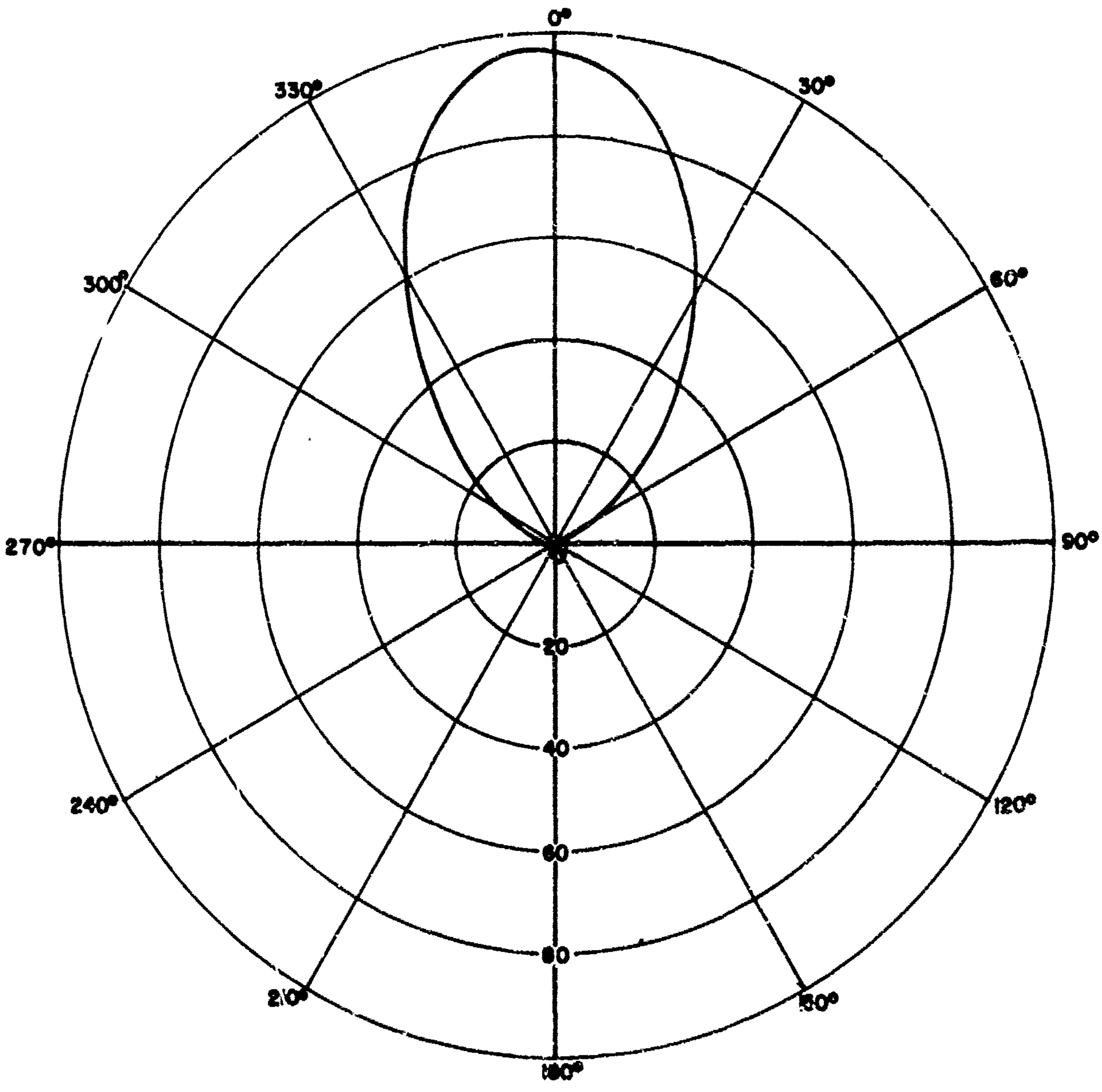

Fig. 43 RADIATION PATTERN OF APN-109B ANTENNA (E-PLANE, 200MHz)

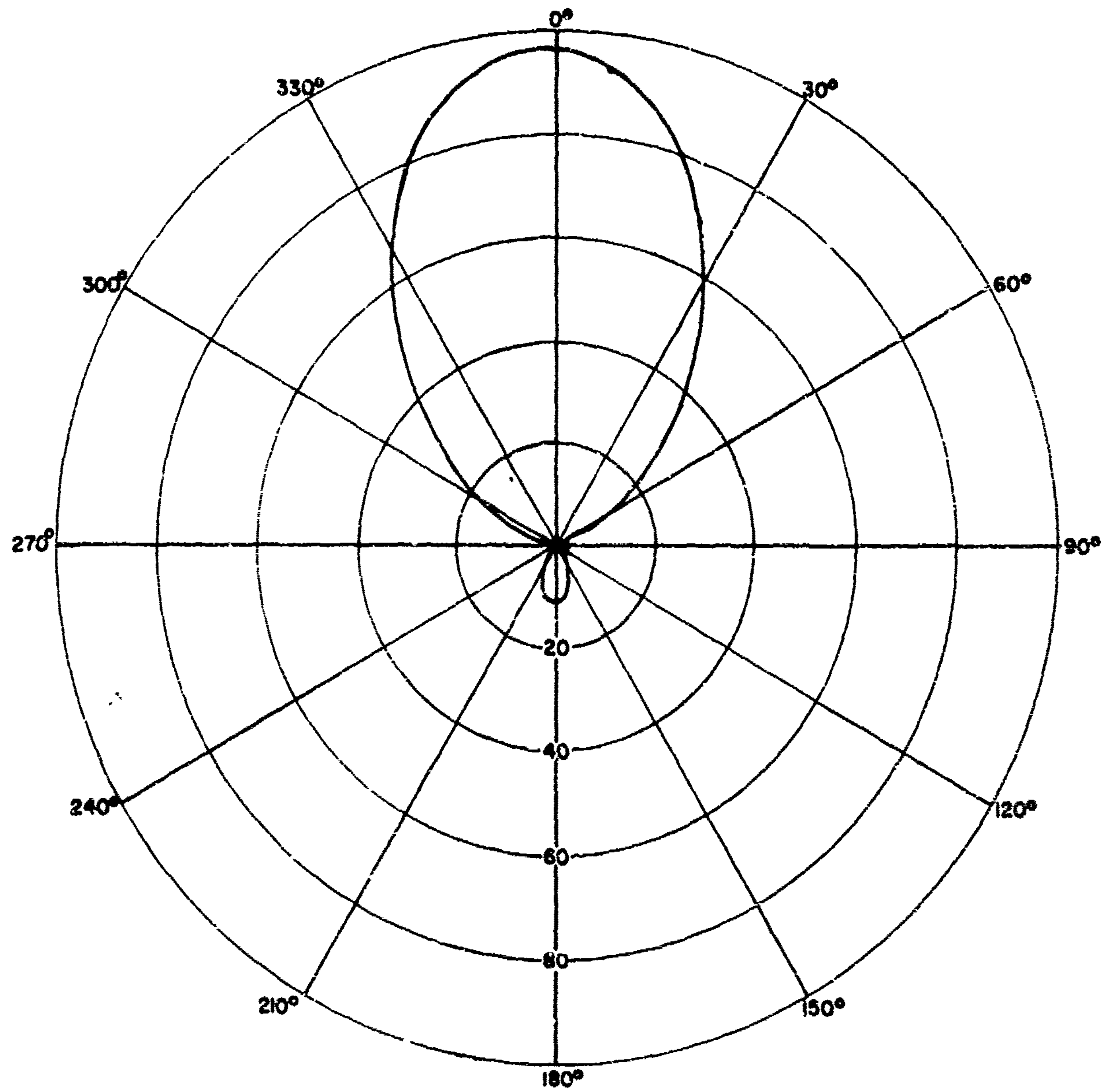

Fig. 44 RADIATION PATTERN OF APN-109B ANTENNA (H-PLANE, 200 MHz)

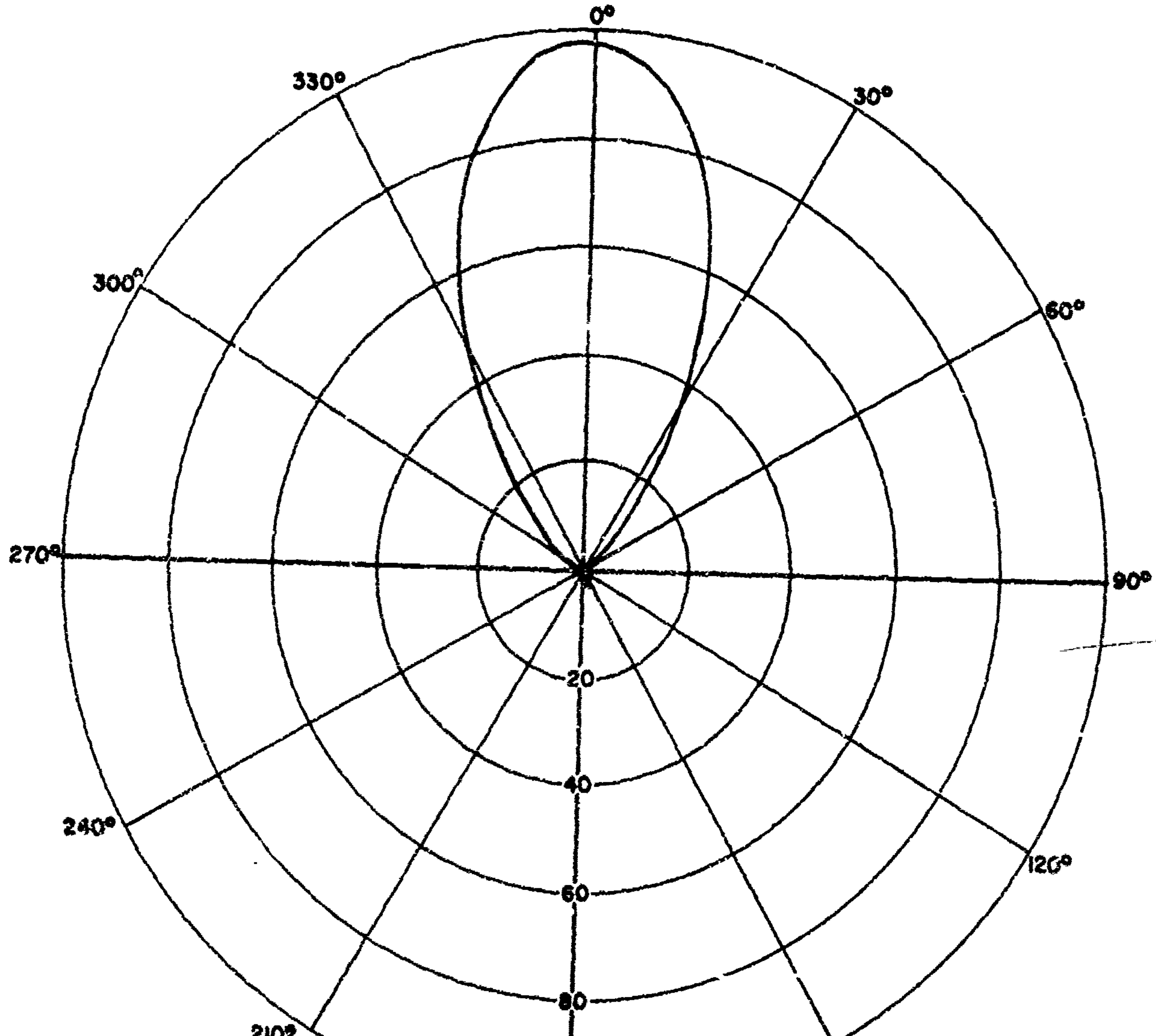

Fig.45 RADIATION PATTERN OF APN-109B ANTENNA (E-PLANE, 300MHz)

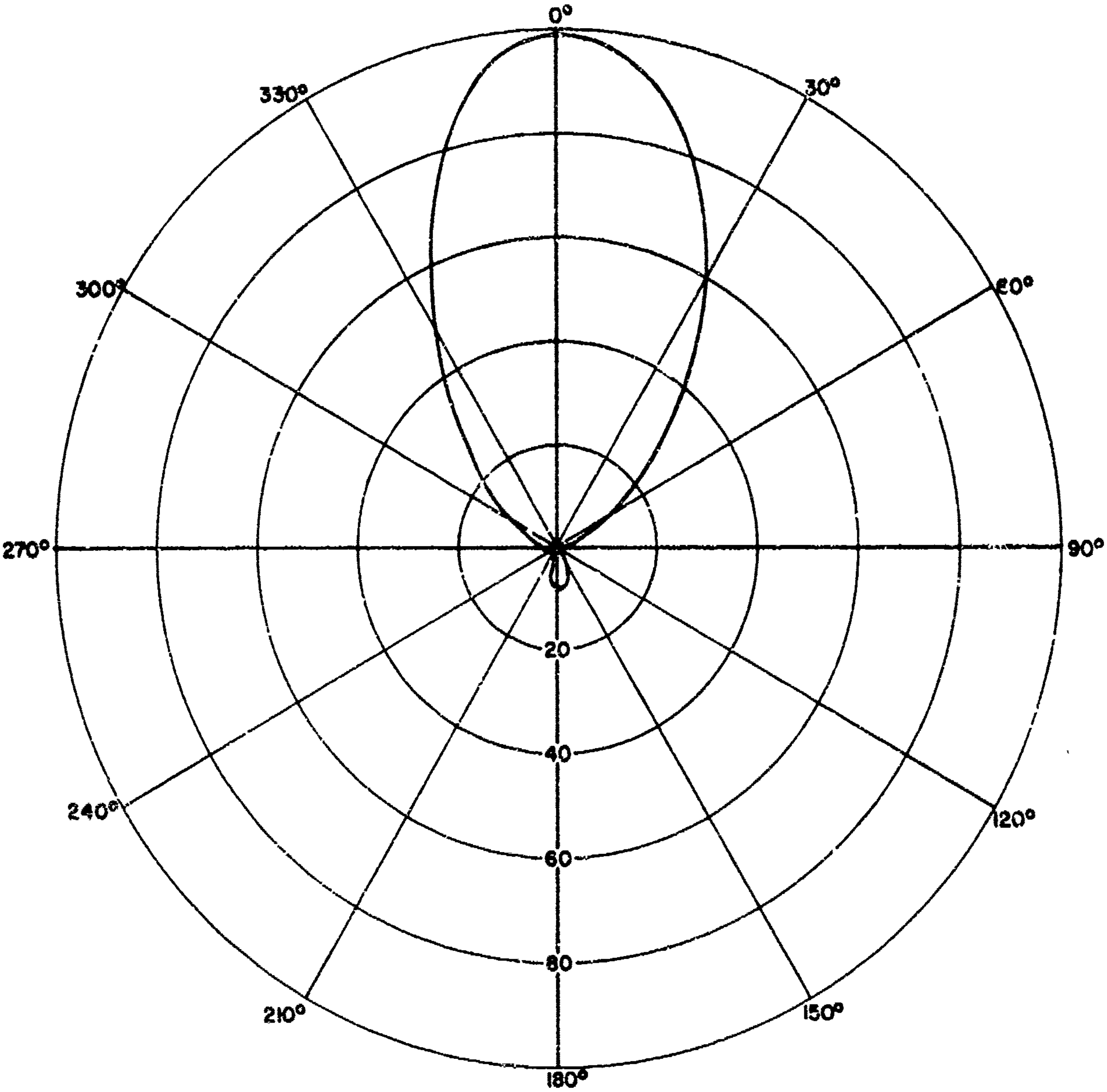

Fig. 4 6 RADIATION PATTERN OF APN-109B ANTENNA (H-PLANE, 300MHz)

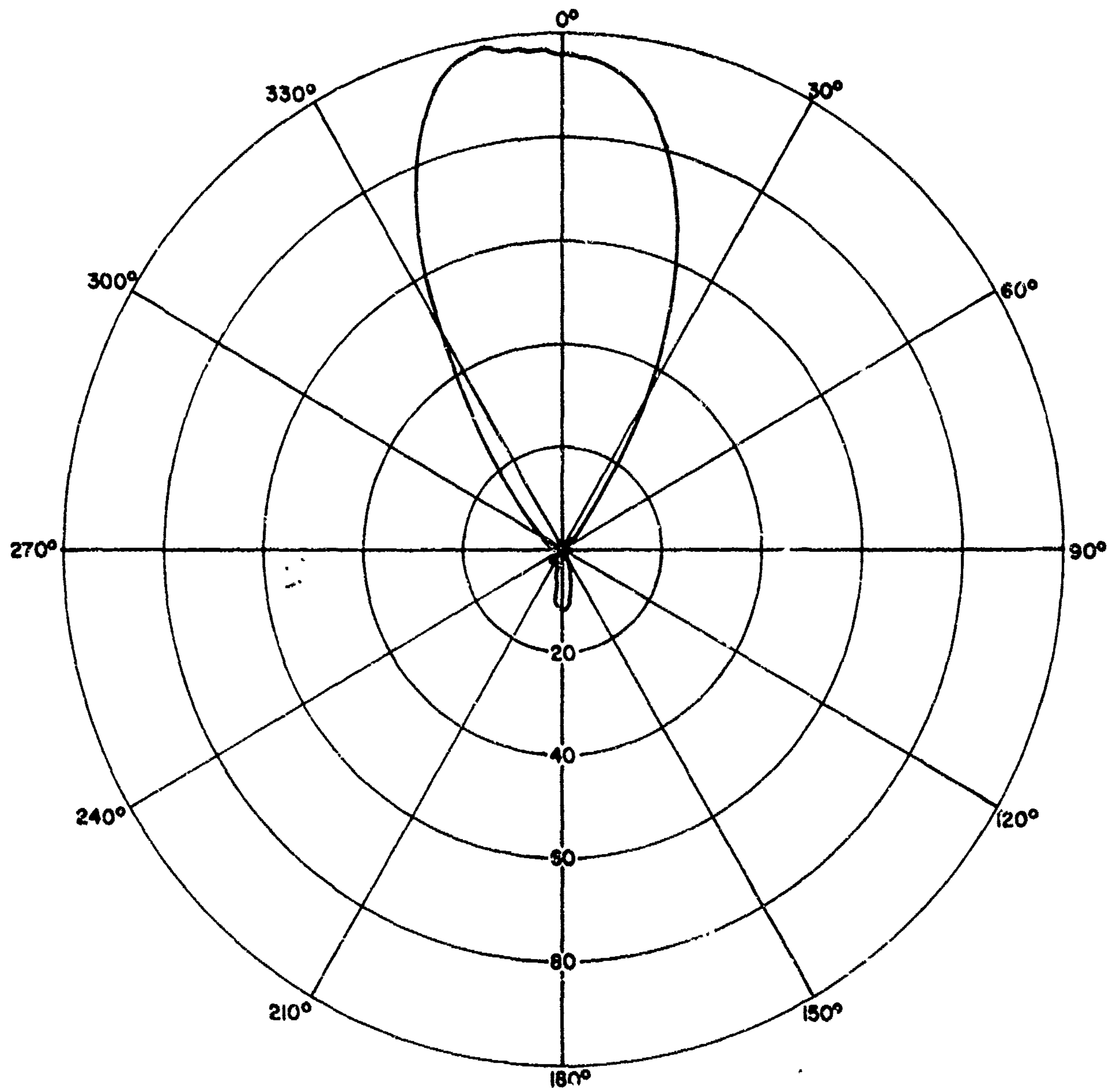

Fig. 47 RADIATION PATTERN OF APN-109B ANTENNA (E-PLANE, 500MHz)

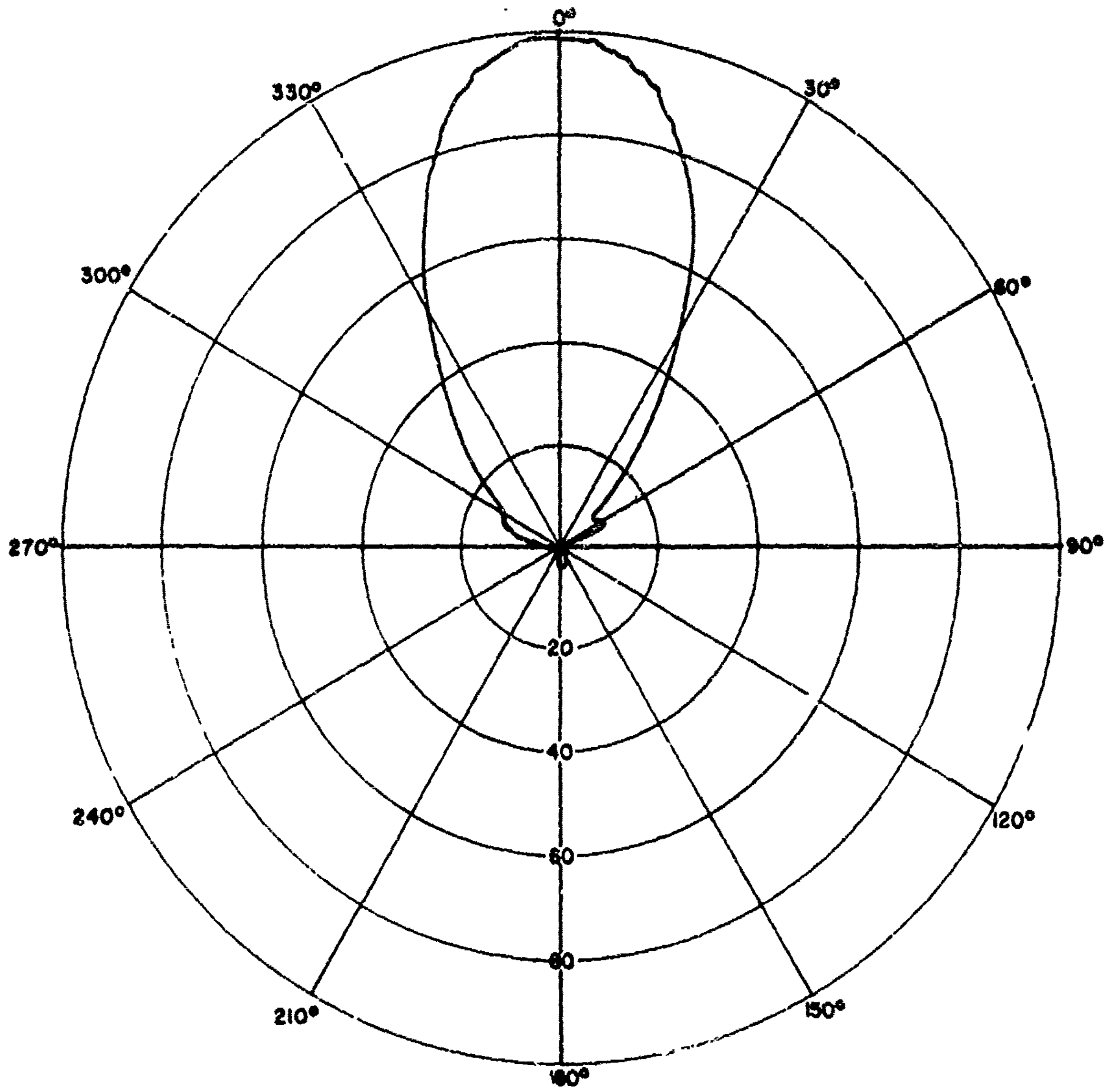

Fig. 48 RADIATION PATTERN OF APN-109B ANTENNA (H-PLANE, 500MHz)

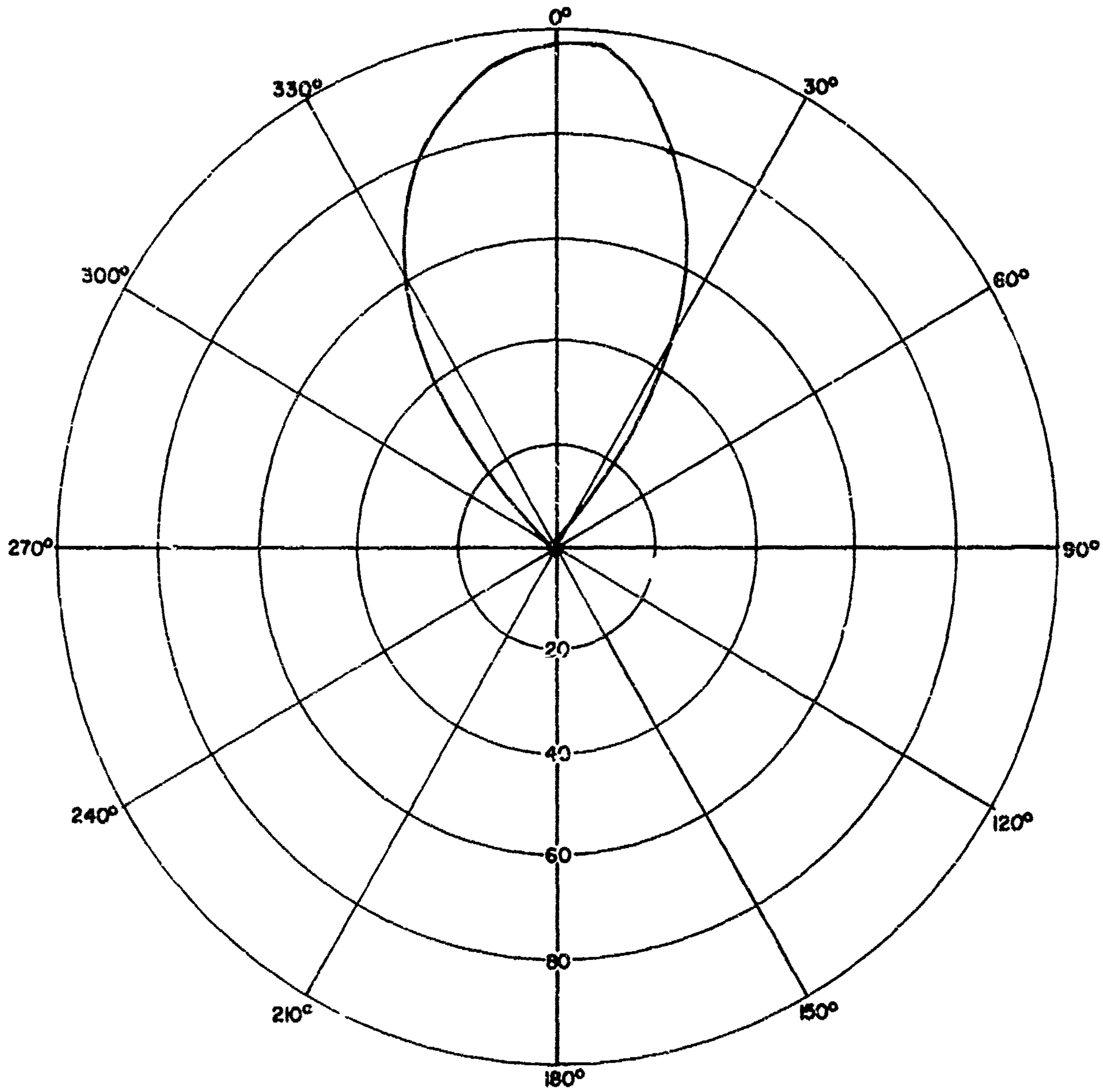

Fig. 49 RADIATION PATTERN OF APN-109B ANTENNA (E-PLANE, 700MHz)

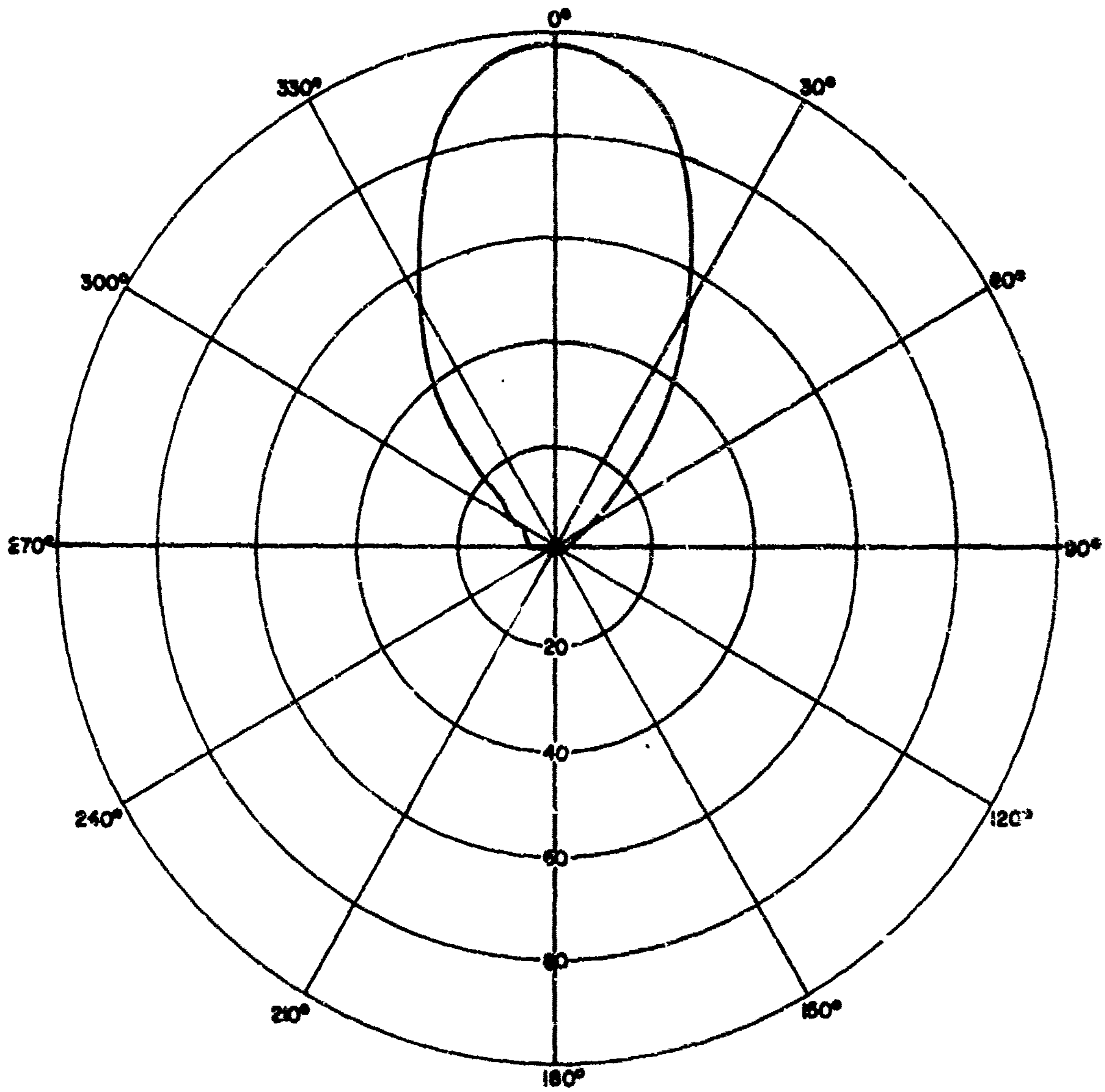

Fig. 50 RADIATION PATTERN OF APN-109B ANTENNA (H-PLANE, 700MHz)

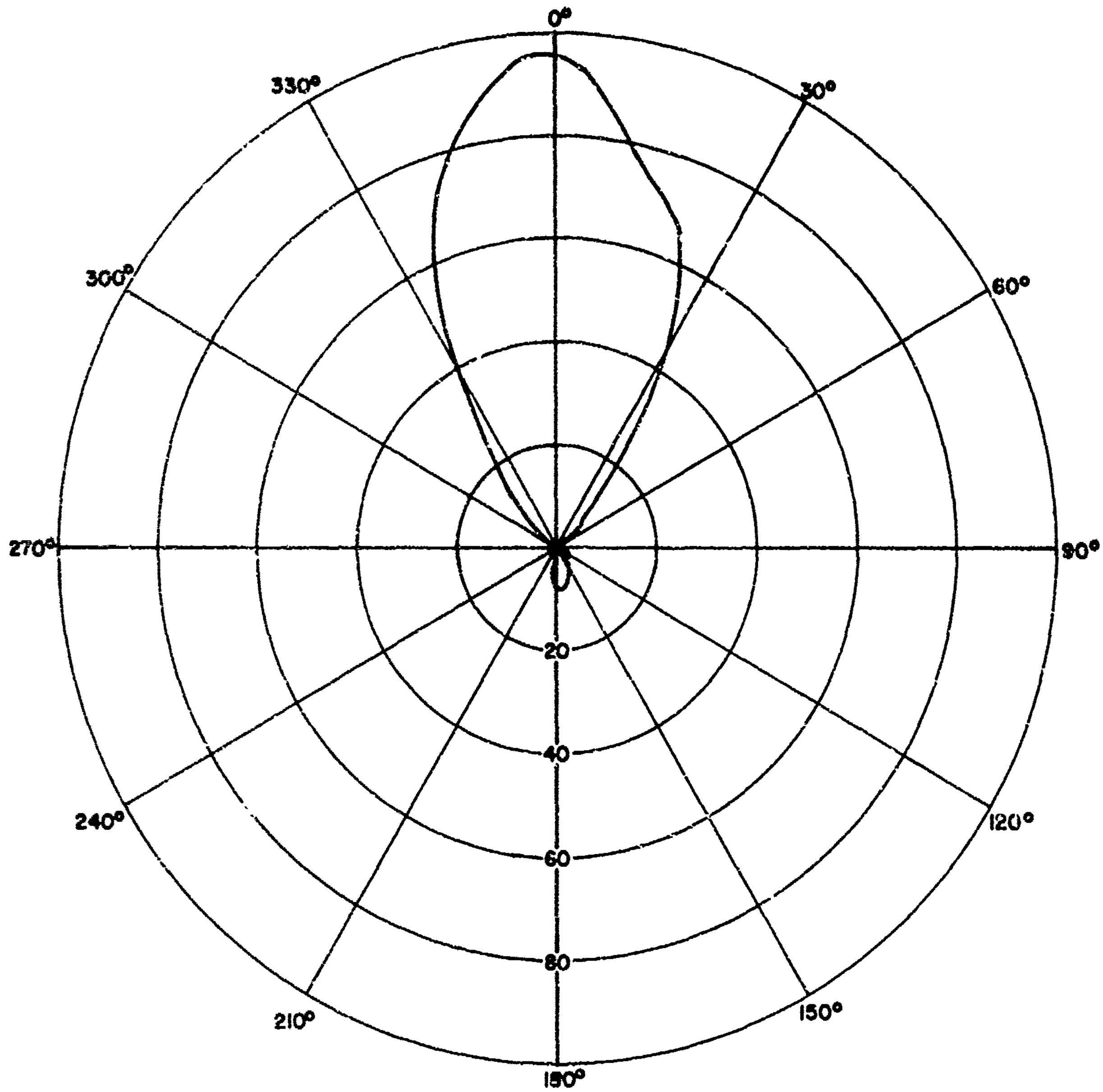

Fig.51 RADIATION PATTERN OF APN-109B ANTENNA (E-PLANE, 900Mhz)

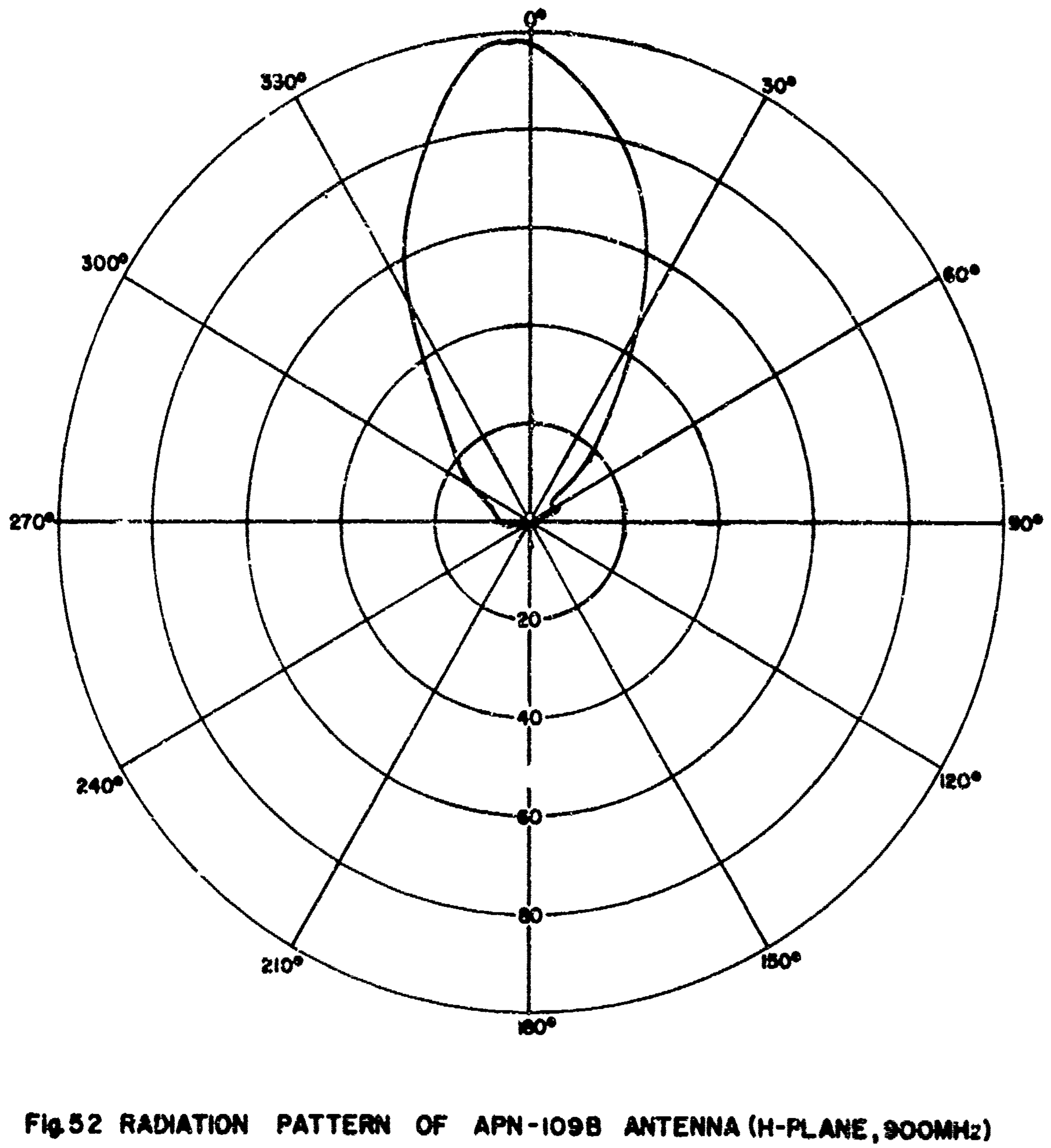

Fig.52 RADIATION PATTERN OF APN-109B ANTENNA (H-PLANE, 900MHz)

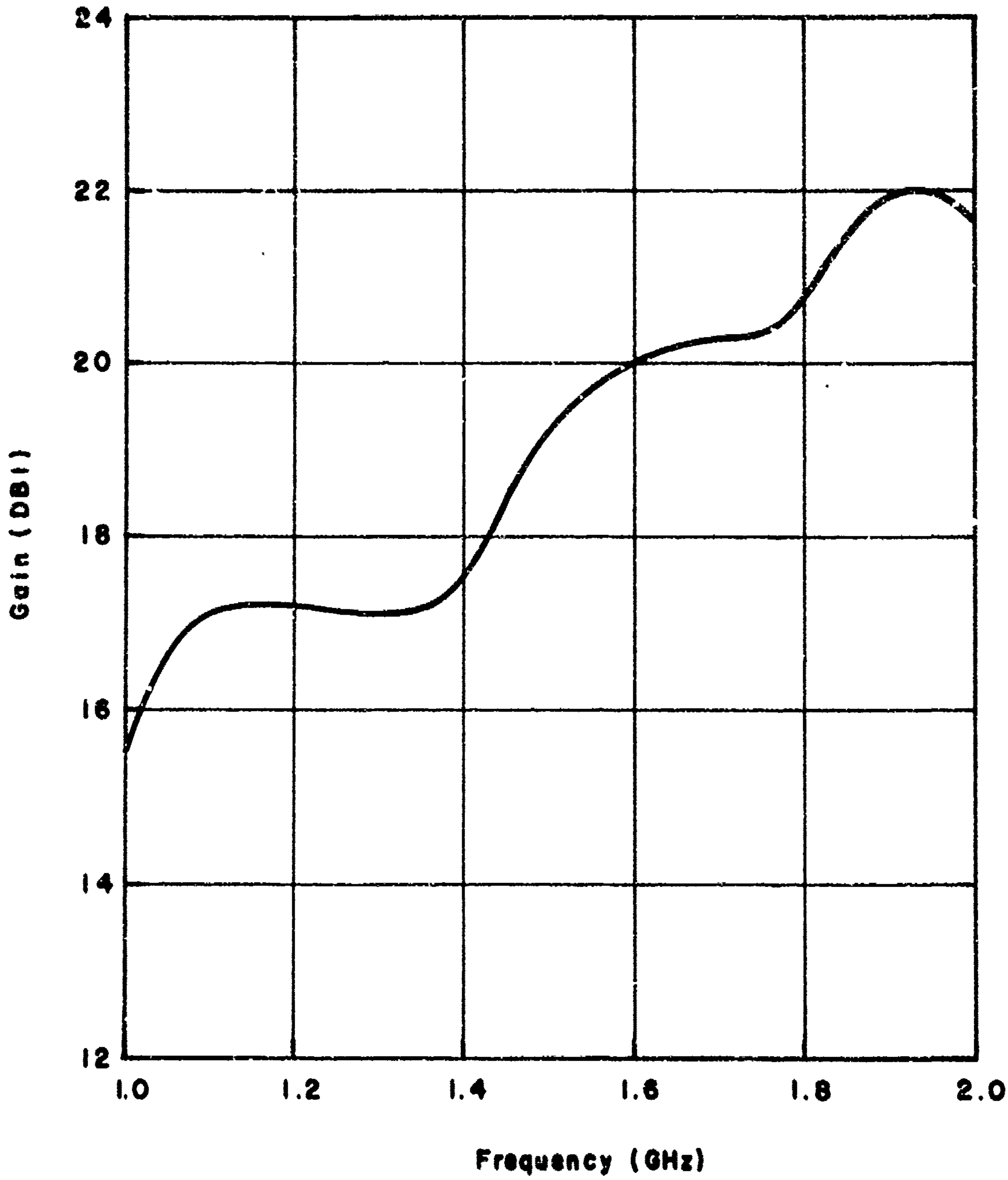

Fig. 53 GAIN OF 4133-LI-N TOWER RECEIVING DISH ANTENNA

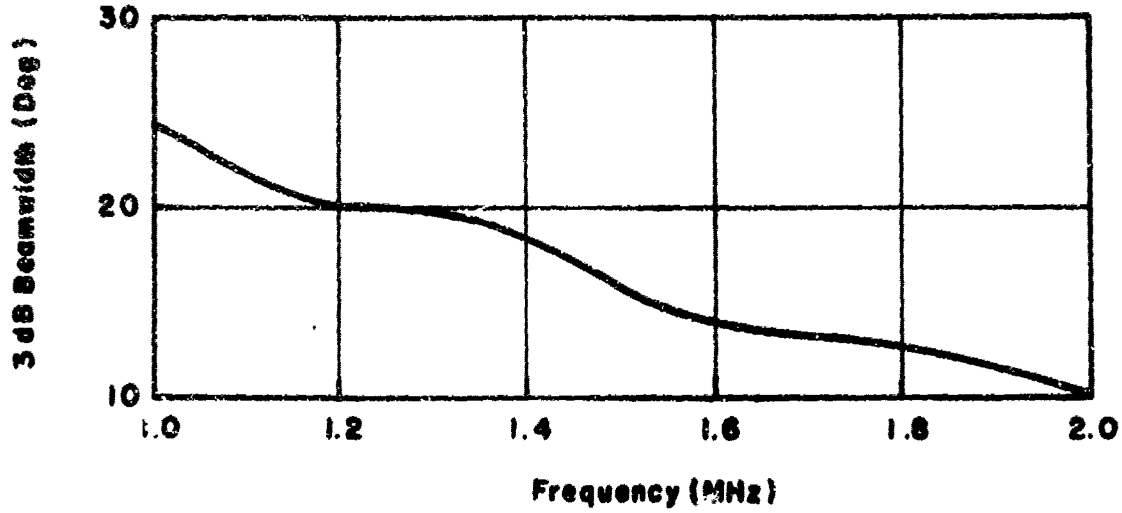

Fig. 54 BEAMWIDTH OF 4133-LI-N TOWER RECEIVING DISH ANTENNA

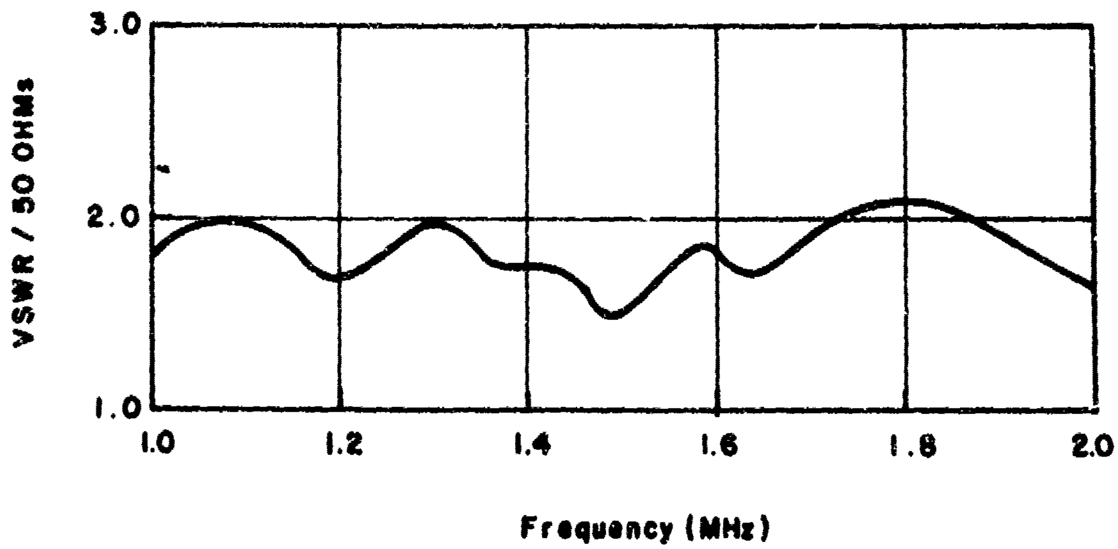

Fig. 55 VSWR OF 4133-LI-N TOWER RECEIVING DISH ANTENNA

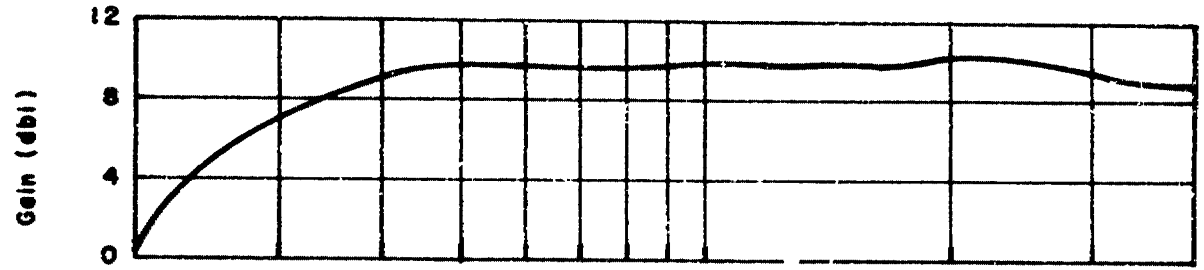

Fig. 56 GAIN OF 2302-LI-N TOWER AND GROUND RECEIVING LOG PERIODIC ANTENNAS

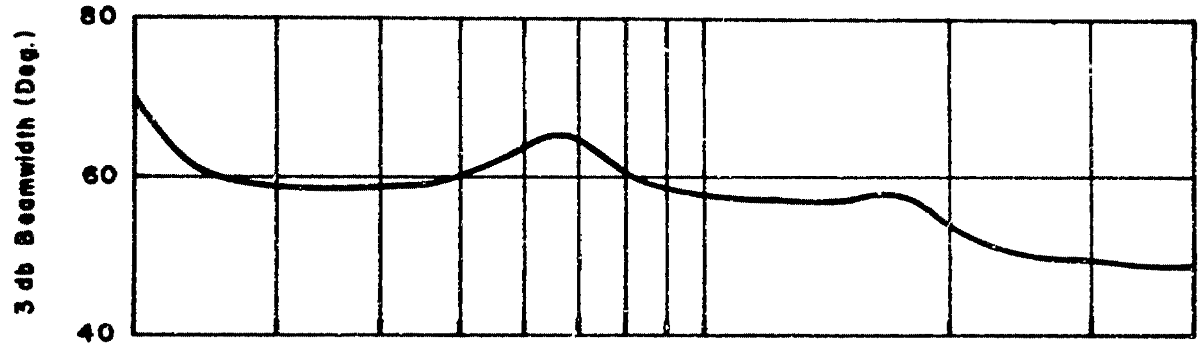

Fig. 57 BEAMWIDTH OF 2302-LI-N TOWER AND GROUND RECEIVING LOG PERIODIC ANTENNAS

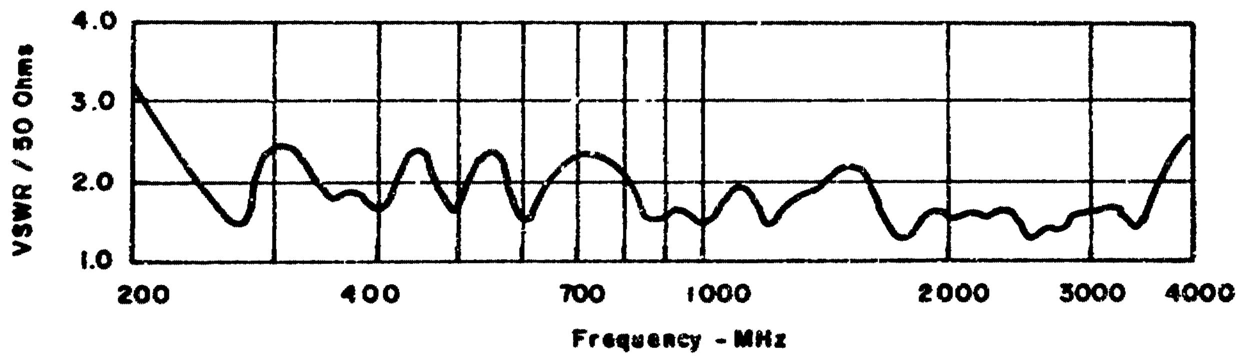

Fig. 58 VSWR OF 2302-LI-N TOWER AND GROUND RECEIVING LOG PERIODIC ANTENNAS

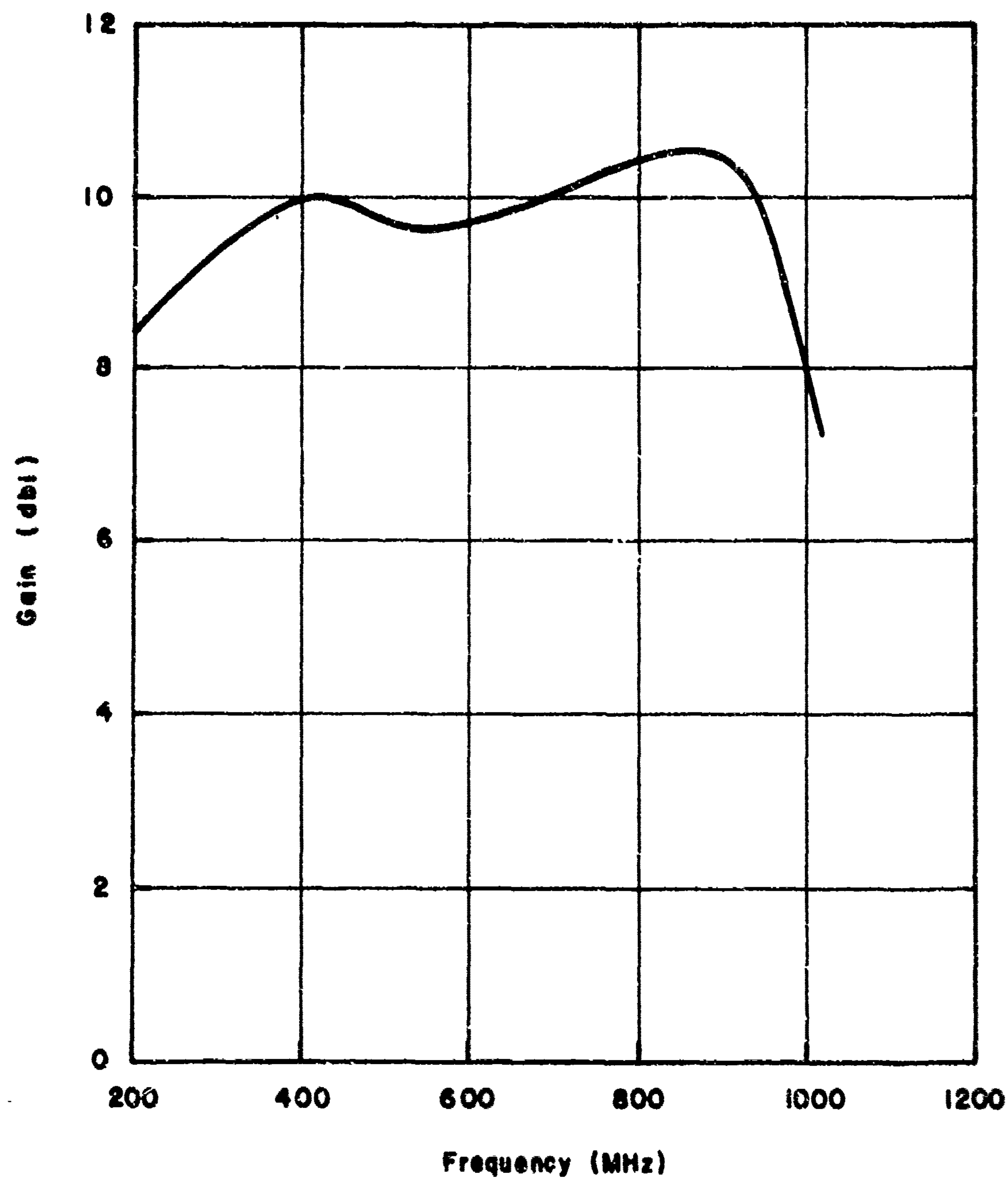

Fig. 59 GAIN OF 2305-LI-N GROUND TRANSMITTING ANTENNA

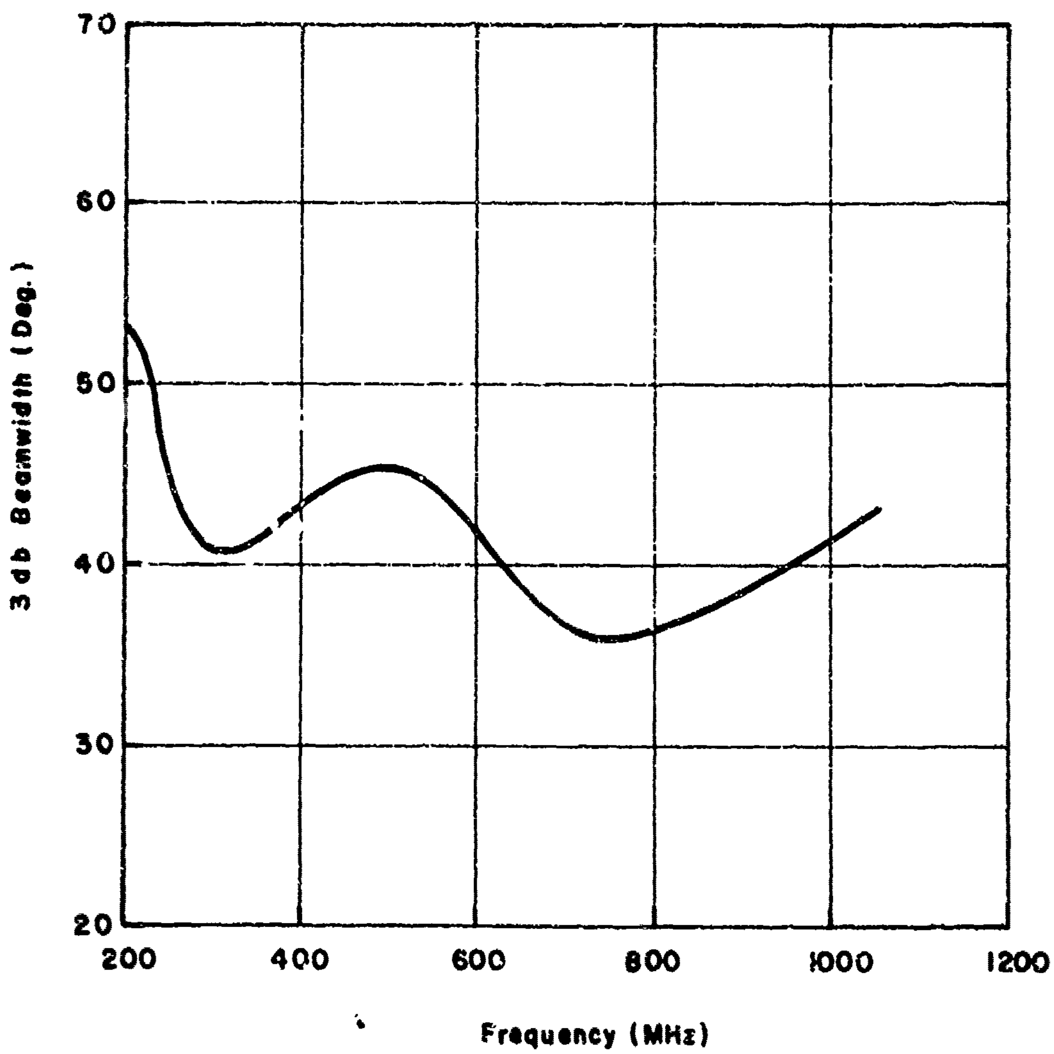

Fig.60 BEAMWIDTH OF 2305-LI-N GROUND TRANSMITTING ANTENNA

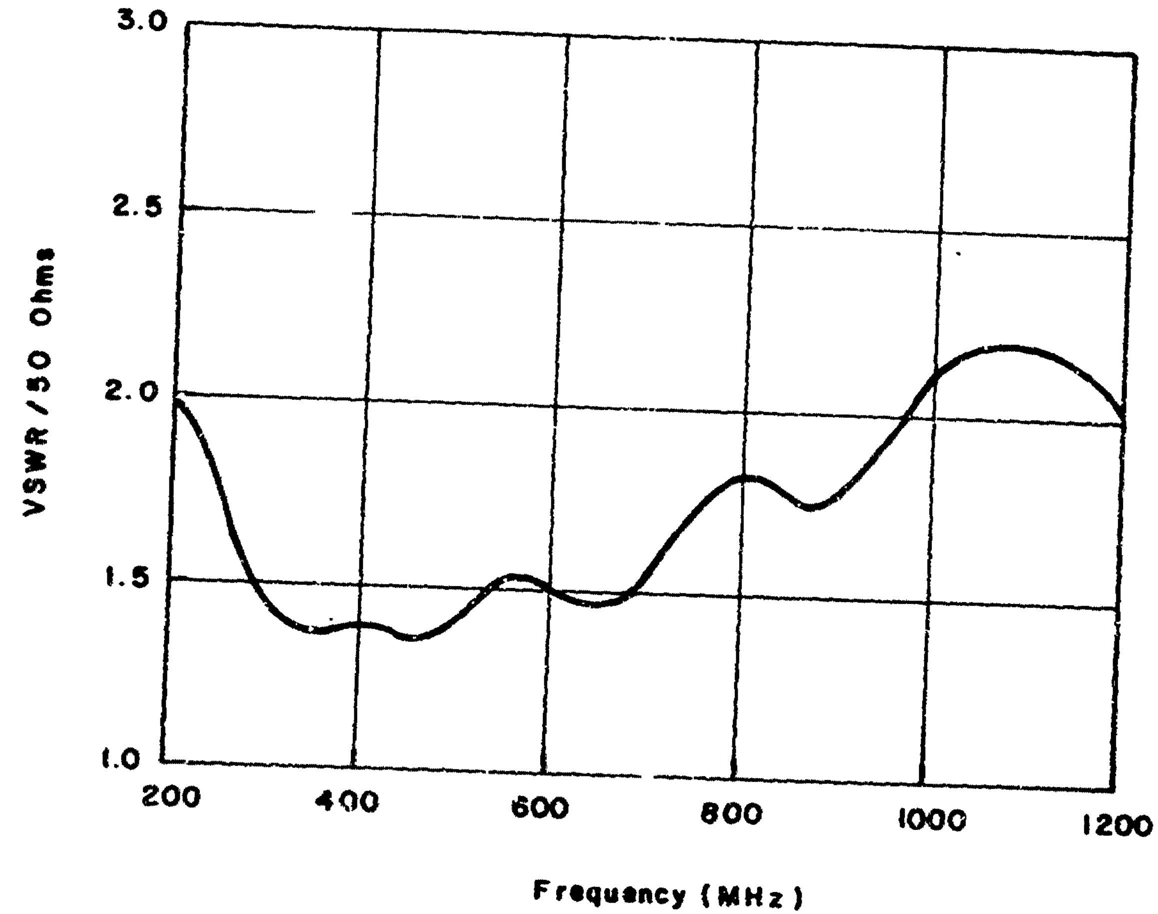

Fig. 61 VSWR OF 2305-LI-N GROUND TRANSMITTING ANTENNA

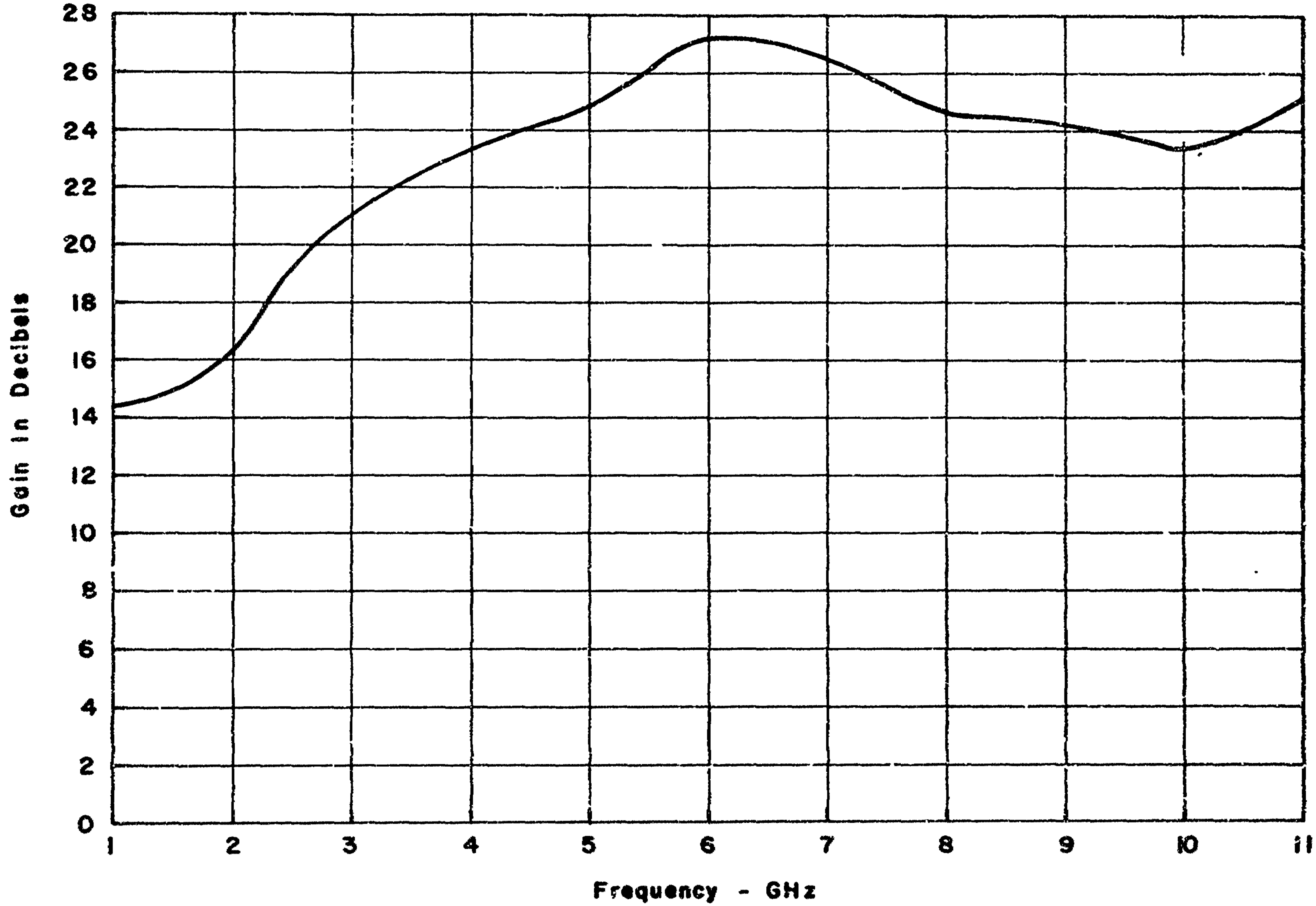

Fig. 62 GAIN OF AT-112 GROUND RECEIVING DISH ANTENNA

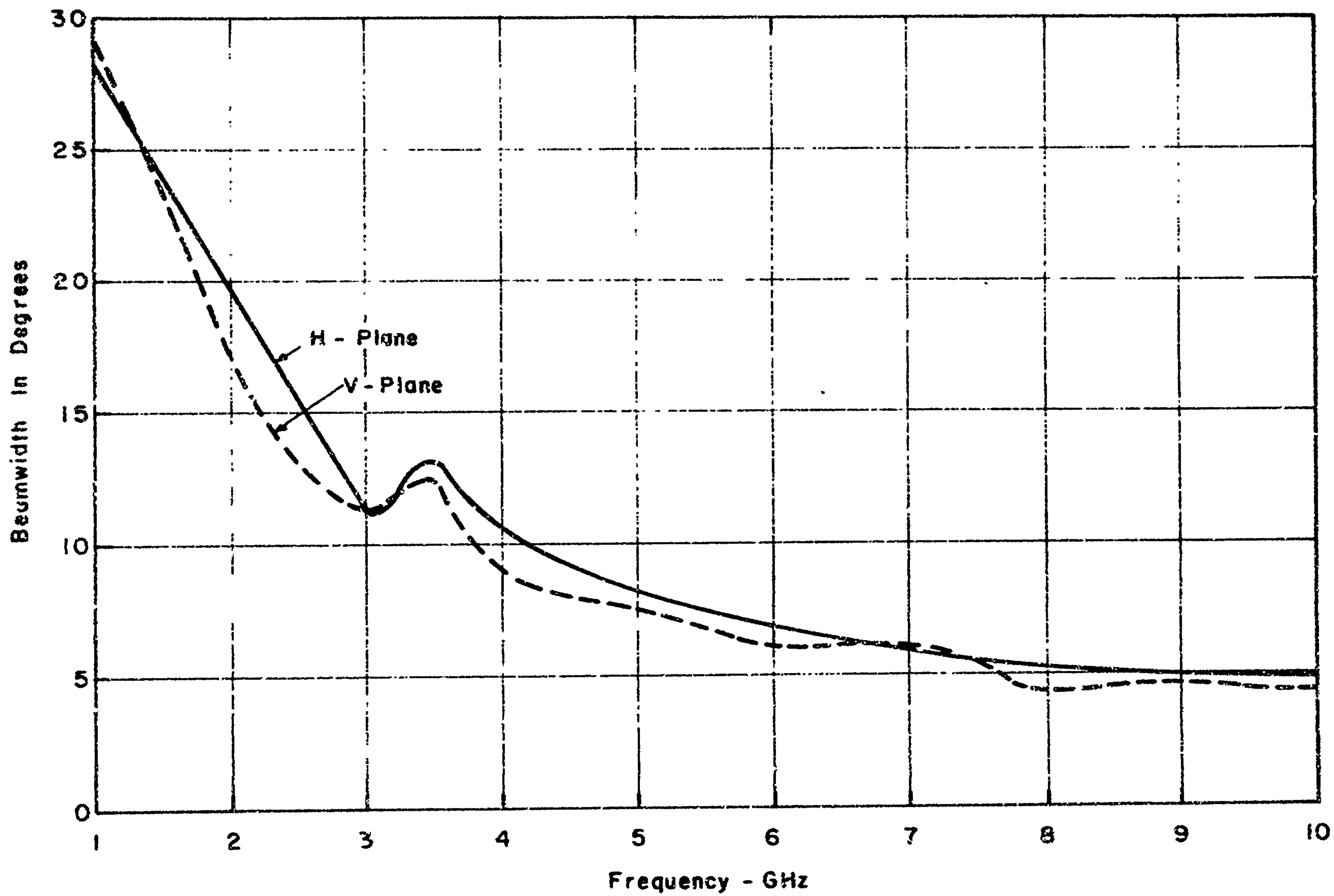

Fig. 63 BEAMWIDTH OF AT-112 GROUND RECEIVING DISH ANTENNA

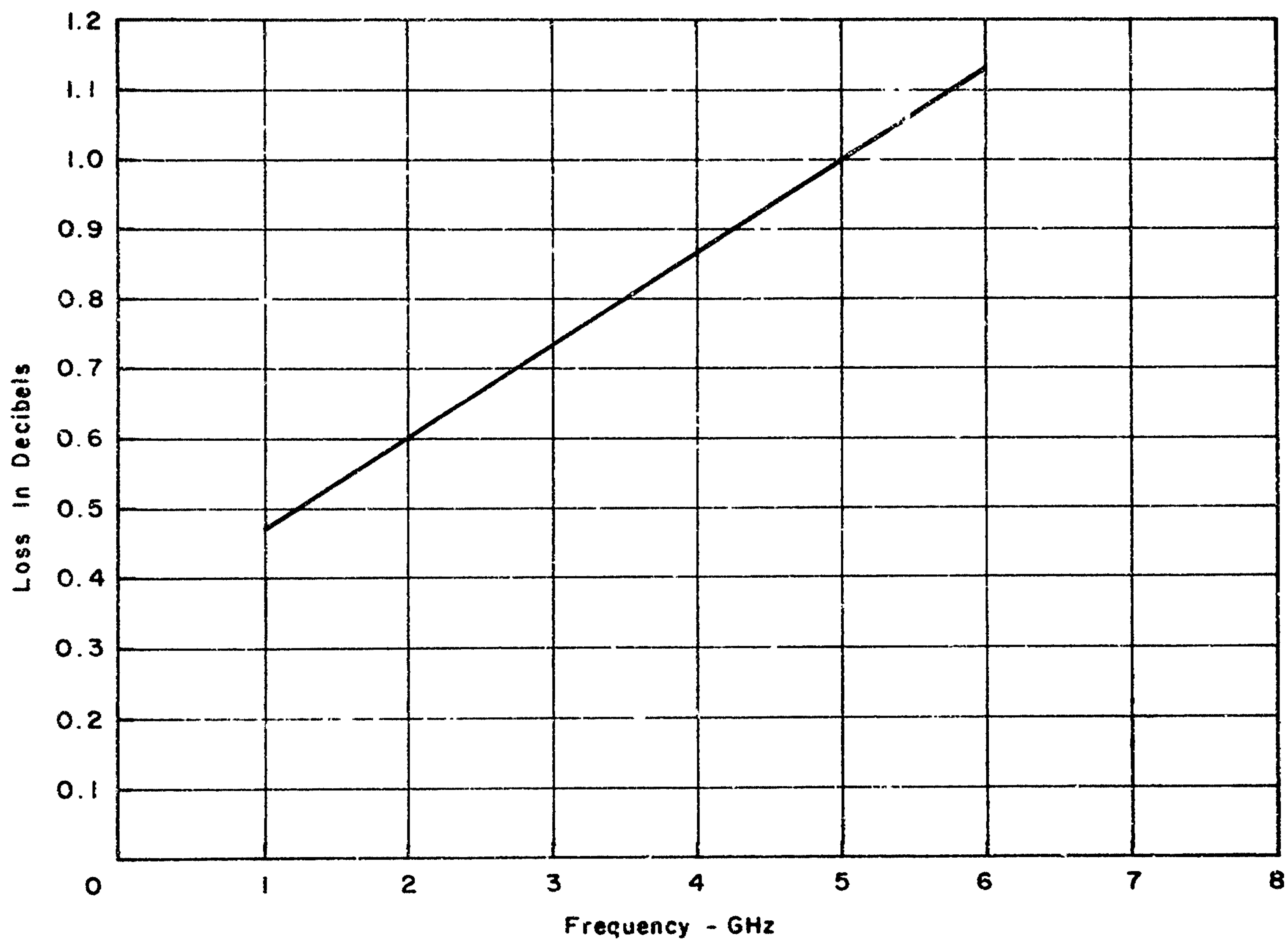

Fig. 64 LOSS FOR 50-INCH RG-9A/U CABLE USED WITH AT-112 GROUND RECEIVING ANTENNA

adjusted so that the no-signal RMS noise level out of the boxcar is 10 mV. The received signal is adjusted, by means of the variable attenuator prior to the pre-amplifier, to provide a nominal 10 volt boxcar output of one channel when the phase shifter is adjusted so that a null exists in the other channel output.

Figures 65-67 show the results of a test performed with a fundamental frequency of 550 MHz, for the purpose of assessing the system noise characteristics. A spectrum analyzer was used to monitor the boxcar output spectrum between approximately 20 Hz and 500 Hz. For the photographs,the display is 50 Hz/div. and the analyzer bandwidth was 10 Hz. The amplitude is logarithmic, with 10 dB/div. and full scale is -10 dBv. The bottom trace in each photograph is a trace of the analyzer noise. The peak in this trace is a zero frequency reference marker. Figure 65 shows the no-signal noise output of the system when the gain was adjusted for 10 mV RMS noise out of the boxcar. Since the bandwidth of the boxcar output is approximately 1 V/Hz, the noise shown in the 10 Hz analyzer bandwidth is approximately -60 dBV or approximately 20 dB below 10 mV.

Using the same analyzer settings as above, Figure 66 shows the low frequency spectral output of the boxcar in the maximized channel, with a signal input to the receiver as described above. For this particular test, the DC signal out of the maximized channel was 8.5 V. Figure 67 shows the spectral output from the minimized channel under the above conditions. It can be seen that very little noise,either AM or FM,is contributed to the low frequency spectrum over and above that of receiver front end noise.

This condition is desirable for future analysis of the target data, since it implies that analysis of modula-

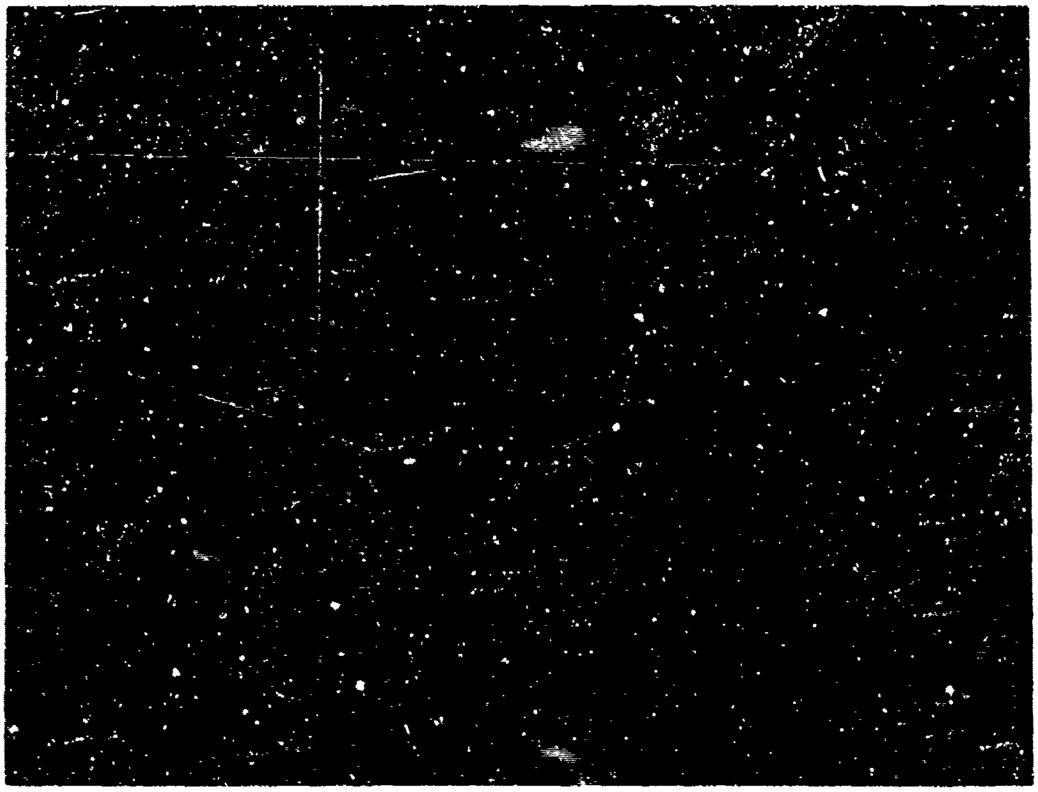

Fig. 65 NOISE OUTPUT SPECTRUM OF ONE CHANNEL OF BOXCAR WITH NO SIGNAL INPUT TO RECEIVER

Input to Receiver
50 Hz/div. Log Ref = 10 dBv

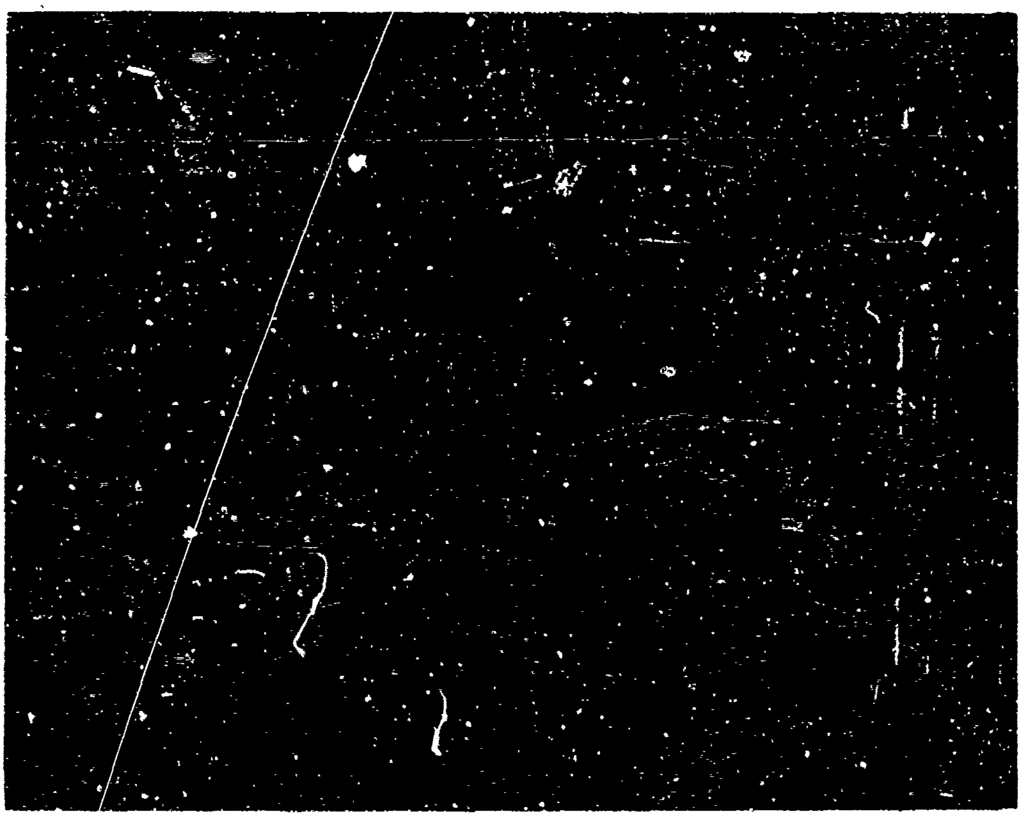

Figure 66 SPECTRUM OF MAXIMIZED CHANNEL OUTPUT OF BOXCAR, DC OUTPUT 8.5V. SAME ANALYZER SETTINGS AS Figure 65

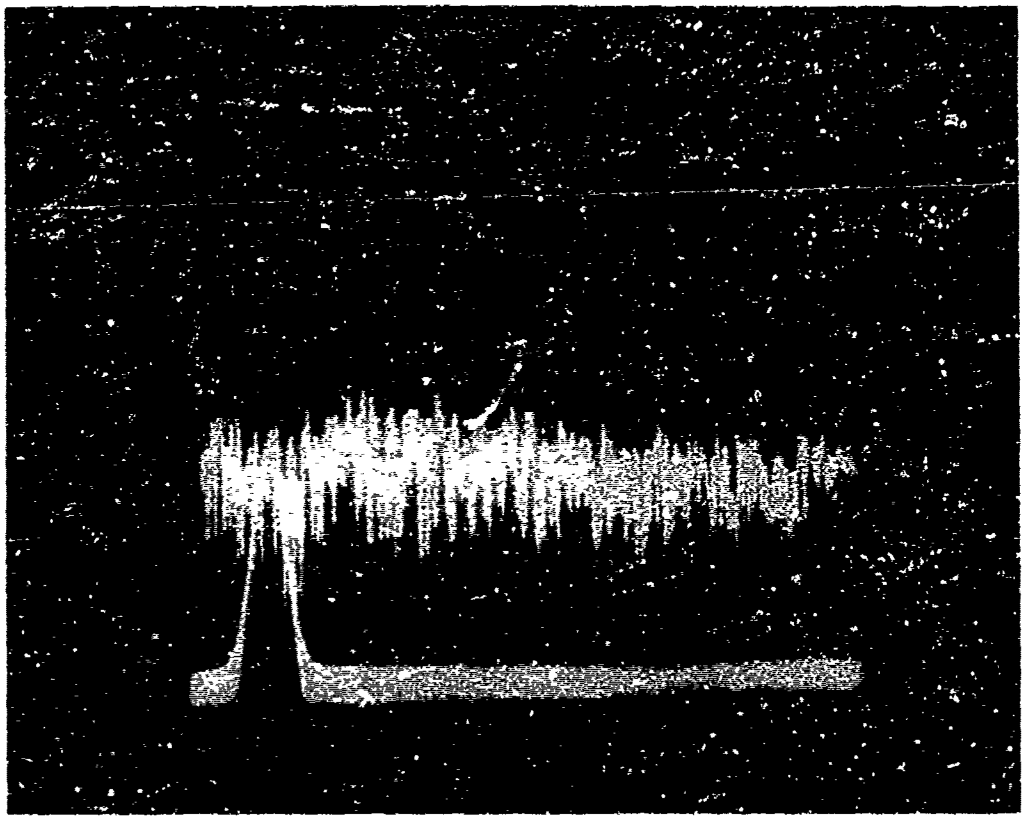

Figure 67 SPECTRUM OF MINIMIZED CHANNEL OUTPUT OF BOXCAR, DC. OUTPUT LESS THAN 10 mV SAME ANALYZER SETTINGS AS Figure 65

tions (above approximately 10 Hz) on the return which are induced by the target are only limited by receiver noise, for all input signal levels up to output saturation, which is 10 V. Under these conditions, the AC noise in each channel can be evaluated. The noise in the maximum channel is essentially that due to amplitude modulation. The noise in the minimum channel is essentially due to frequency modulation.

5.9 Data System

Table X shows a typical performance curve of the Data System, using a variable DC input to the A/D converter, using the test method described in Paragraph 6.5.1.

Input D.C. Voltage	A/D $Output_8$	Converted A/D DC Output Voltage	% Deviation
0	0	0	0
1.106	342	1.1040	-0.18
2.173	675	2.1739	+0.041
3.435	1277	3.4342	-0.023
5.419	2125	5.4176	-0.025
9.990	3772	9.975	+0.15
-1.122	7431	-1.128	+0.53
-2.392	7026	-2.3937	+0.071
-3.601	6436	-3.6052	+0.116
-5.538	5622	-5.5398	+0.032
-10.000	4007	-9.9706	+0.294

TABLE X TYPICAL CALIBRATION DATA

6. MAINTENANCE AND CALIBRATION

6.1 General

Periodic preventive maintenance will insure that small problems will be corrected before they become large problems.

6.1.1 Heliax Lines

Air pressure inside 1/2 inch and 7/8 inch Heliax coaxial cables should be checked periodically. These cables are used within the van and between the van exterior and the antennas. Should a cable become de-pressurized, moisture can collect within the cable and either short the inner and outer conductors or cause cable VSWR to increase. The 1/2 inch Heliax should be pressurized to between 5 and 12 pounds as shown on the gauge located on each pressurized cable. A 7/8 inch Heliax should be pressurized to between 12 and 18 pounds.

6.1.2 Transmitter Air Filters

There are two sets of air filters in the transmitter: the blower filters and cavity filters.

The blower air filters are located behind grills at the lower fronts of each transmitter rack. These should be removed and cleaned with air or water once every month. If water or air are not available, a temporary cleaning can be effected by sharply tapping the filter against a solid object.

Each of the vacuum tube cavities (10 watt, 100 watt, 1 kW and 5 kW) has air filters made of metal screen. Input screen filters are located within the metal tubes to which the flexible air hoses attach. Air exit filters are located on the cavities themselves. All of these screen air

filters should be cleaned perhaps once a month, using solvents and swabs.

6.1.3 Air Conditioner Filter

The air conditioner filter is located in the air-conditioning ducting, over the truck cab's right hand door.

6.1.4 Engines

At least once every two weeks, the truck engine (as well as the shop van engine) should be run until it has come up to operating temperature. If the VP METRRA generator has been inoperative, it also should be run.

6.1.5 Storage Batteries

Storage batteries within the vehicles and other storage batteries used with the VP METRRA system should be chacked about every two weeks. Both fluid level and stage-of-charge should be checked.

6.1.6 Ground Rods

Ground rods on the generators, oil tank, and 50-foot tower should be checked periodically to insure that they are in good condition. The inspector should check for loose connections and corrosion.

6.2 Calibration of Transmitter Monitor

1. Temporarily short the TRANSMITTER MONITOR jack.

2. Adjust the BALANCE potentiometer to obtain zero DC output at the DC OUT jack. The circuit board containing this component is located in the rear of the boxcar unit.

3. Remove the short from the TRANSMITTER MONITOR jack.

4. Apply 0.27 VDC to the TRANSMITTER MONITOR jack and adjust the gain control until the output of the DC OUT jack is 10.0 VDC.

5. The transmitter monitor is now calibrated.

6.3 Wet Coaxial Filters

Despite reasonable protection from rain and snow, it is possible that transmitting and receiving low-pass and bandpass filters may become wet internally. Should this occur, a wet filter will usually show radically changed characteristics such as increased insertion loss, high system VSWR, etc. Wet filters can be dried out as described below, per manufacturers' instructions.

Cir-Q-Tel Filters

1. Bake for 1/2 hour at 250° F.
2. After filter has cooled to room temperature, tape over joints between body and end bells. Use at least six thicknesses of Scotch Electrical Tape No. 33+ or equivalent. Pull tape tightly while applying.

Telonic Filters

1. Bake for two hours at 176° F.
2. After filter has cooled to room temperature, tape over joints between body and end bells. Use at least six thicknesses of Scotch Electrical Tape No. 33+ or equivalent. Pull tape tightly while applying.

6.4 System Calibration

6.4.1 Measurement of Third Harmonic Target Cross Section

A simplified block diagram of the Vehicular Variable-Parameter METRRA System is shown in Figure 54. Only the transmit and receive sections are included here. The computer and signal recording section is not shown since this part of this system is not necessary for this discussion. The problem that is posed regarding the transmit and receive system is: What is a target's effective cross section if the amplitude of the receive signal and the transmitter power output are known? Obviously, this question must be answered with a mathematical expression relating the received signal amplitude and transmitted power with the target cross section.

In order for this expression to be developed, some terms involving the transmit and receive sections will be defined.

By definition, from Figure 68 :

P_{TO} = transmitter output power

L_{TC} = transmit cable loss including loss of directional coupler and low pass filter

P_{TA} = RF power level at transmit antenna

L_{TA} = path loss measured at f_o from transmit antenna to target. By definition, L_{TA} is the ratio of the transmitted power (P_{TA}) to the f_o power density ($\overline{P}$) at the target.

σ = Nonlinear scattering cross section of target

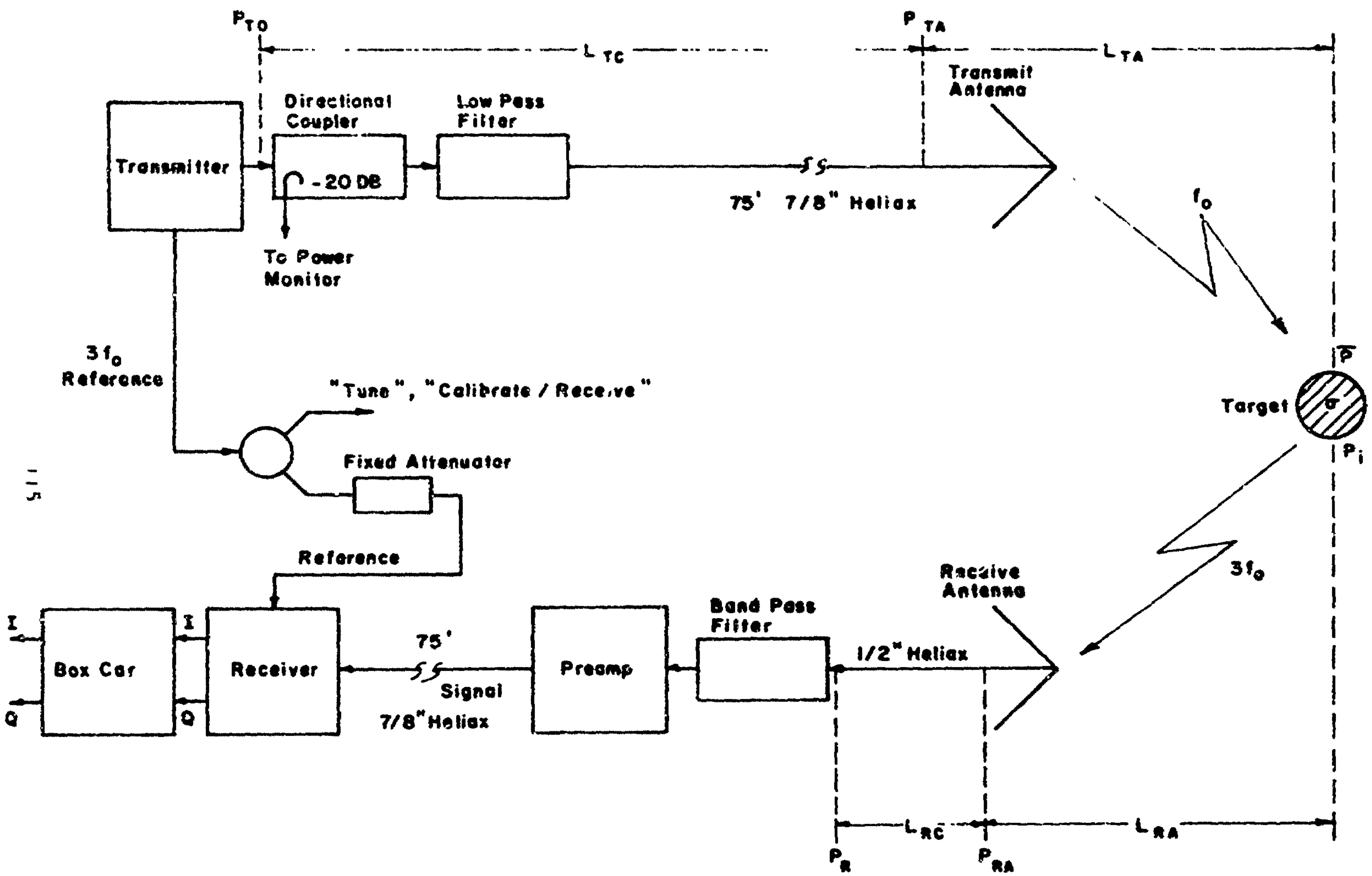

Fig. 68 TRANSMIT AND RECEIVE SYSTEM

L_{RA} = path loss measured at 3 f_o from target to receive antenna, defined as the ratio of the power delivered to an isotropic antenna at the target location to the power output from the receiving antenna

P_{RA} = total 3 f_o power received by receive antenna

L_{RC} = loss in cable between receive antenna and receive filter

P_R = net 3 f_o power going to receive filter

The preamplifier and receiving filter may be thought of as being the "front end" of the receiver.

The boxcar unit has two outputs that are 90° apart in phase. One output, called the I channel, has an output equal to $V_o \cos \phi$. The other output, called the Q channel, is equal to $V_o \sin \phi$. For V_o to be found, the two outputs should be squared, added together, and the square root of the sum should be found. In other words:

$$(V_o \cos \phi)^2 = {V_o}^2 \cos^2 \phi$$

$$(V_o \sin \phi)^2 = {V_o}^2 \sin^2 \phi$$

The sum of the two above terms is:

$$\begin{aligned} {V_o}^2 \cos^2 \phi + V_o^2 \sin^2 \phi &= V_o^2 (\cos^2 \phi + \sin^2 \phi) \\ &= V_o^2 \end{aligned}$$

and the square root of V_o^2 is V_o.

It should be remembered that what is sought is σ as a function of the boxcar output, i.e., $\sigma = F(V_o)$.

From the above definitions and Figure 68,

$$P_{TA} = \frac{P_{TC}}{L_{TC}} \quad \text{(watts)} \tag{1}$$

$$P_R = \frac{P_{RA}}{L_{RC}} \quad \text{(watts)} \tag{2}$$

$$\overline{P} = \frac{P_{TA}}{L_{TA}} \quad \text{(watts/meter}^2\text{)} \tag{3}$$

where $\overline{P}$ is the f_o power density at the target.

$P_i = \sigma \overline{P}$ where P_i is the equivalent 3 f_o power level that would be radiated by an isotropic antenna (gain = 1) at the target's position. (4)

Since power is proportional to the square of the voltage,

$$P_R \propto V_o^2$$

Defining a constant H such that $P_R = H^2 V_o^2$ for a given received power and receiver gain setting, therefore,

$$V_o H = \sqrt{P_R} \tag{5}$$

From equation (2),

$$V_o H = \sqrt{\frac{P_{RA}}{L_{RC}}} \tag{6}$$

From the definitions above, $L_{RA} = \frac{P_i}{P_{RA}}$ or

$$P_{RA} = \frac{P_i}{L_{RA}} \tag{7}$$

Substituting equation (7) into (6), equation (8) is obtained:

$$V_oH = \sqrt{\frac{P_i}{L_{RA}\ L_{KC}}} \tag{8}$$

From (4),

$$V_oH = \sqrt{\frac{\bar{P}\sigma}{L_{RC}\ L_{RA}}} \tag{9}$$

From (3),

$$V_oH = \sqrt{\frac{P_{TA}\sigma}{L_{RC}\ L_{RA}\ L_{TA}}} \tag{10}$$

From (1),

$$V_oH = \sqrt{\frac{P_{TO}\sigma}{L_{RC}\ L_{RA}\ L_{TA}\ L_{TC}}} \tag{11}$$

From equation (11),

$$V_o^2H^2 = \left(\frac{P_{TO}}{L_{RC}\ L_{RA}\ L_{TA}\ L_{TC}}\right)\sigma$$

Thus, the equation being sought is

$$\sigma = V_o^2H^2 \left(\frac{L_{RC}\ L_{RA}\ L_{TA}\ L_{TC}}{P_{TO}}\right) ,$$

or

$$\sigma = (KV_o)^2 \tag{12}$$

where

$$K = H\sqrt{\frac{L_{RC}\ L_{RA}\ L_{TA}\ L_{TC}}{P_{TO}}} \tag{13}$$

6.4.2 Calculation of K and H from Experimental Data

In order for calculations of K and H to be obtained, it is necessary to find the values of the losses and other

terms in the equations above. Before K can be calculated, H must first be found. The constant H is calculated from equation (5) above; that is,

$$H = \frac{\sqrt{P_R}}{V_o}$$

where P_R is the power level, in watts, of the signal at the input to the receiving bandpass filter and V_o is obtained by measuring the outputs of the two boxcar channels and squaring, as described above. An alternate and simpler method is to use the phase shifter shown in Figure 69 to adjust ϕ so that the signal appears only in one channel; i.e., a null appears in the other channel. Under these conditions, the output of the maximized channel is V_o. The switch would be in "CALIBRATE/RECEIVE position." The antenna is connected for "Receive," and the seventy-five foot calibrate cable (RG-9/U) is connected (in place of the cable from the receiving antenna) to the bandpass filter when the receiving system is being calibrated. V_o is the absolute value of the voltage out of a maximized boxcar channel. The usual procedure is to feed a -100 dBm signal into the receiving bandpass filter. Then the IF gain of the receiver is set so that the noise voltage on the RMS meter is 10 mV. At this point, the IF gain knob setting and voltage V_o are noted. Then the RMS noise voltage is increased by 5 dB, and the IF knob setting and the voltage V_o are again noted. This is repeated until one volt is reached on the RMS meter. The power level is kept constant at -100 dBm during this time. The reason for using this power level is that if the signal were larger, limiting might be reached by the receiver. On the other hand, the sensitivity of the receiver is on the order of -113 dBm, so the signal has to be at least that level.

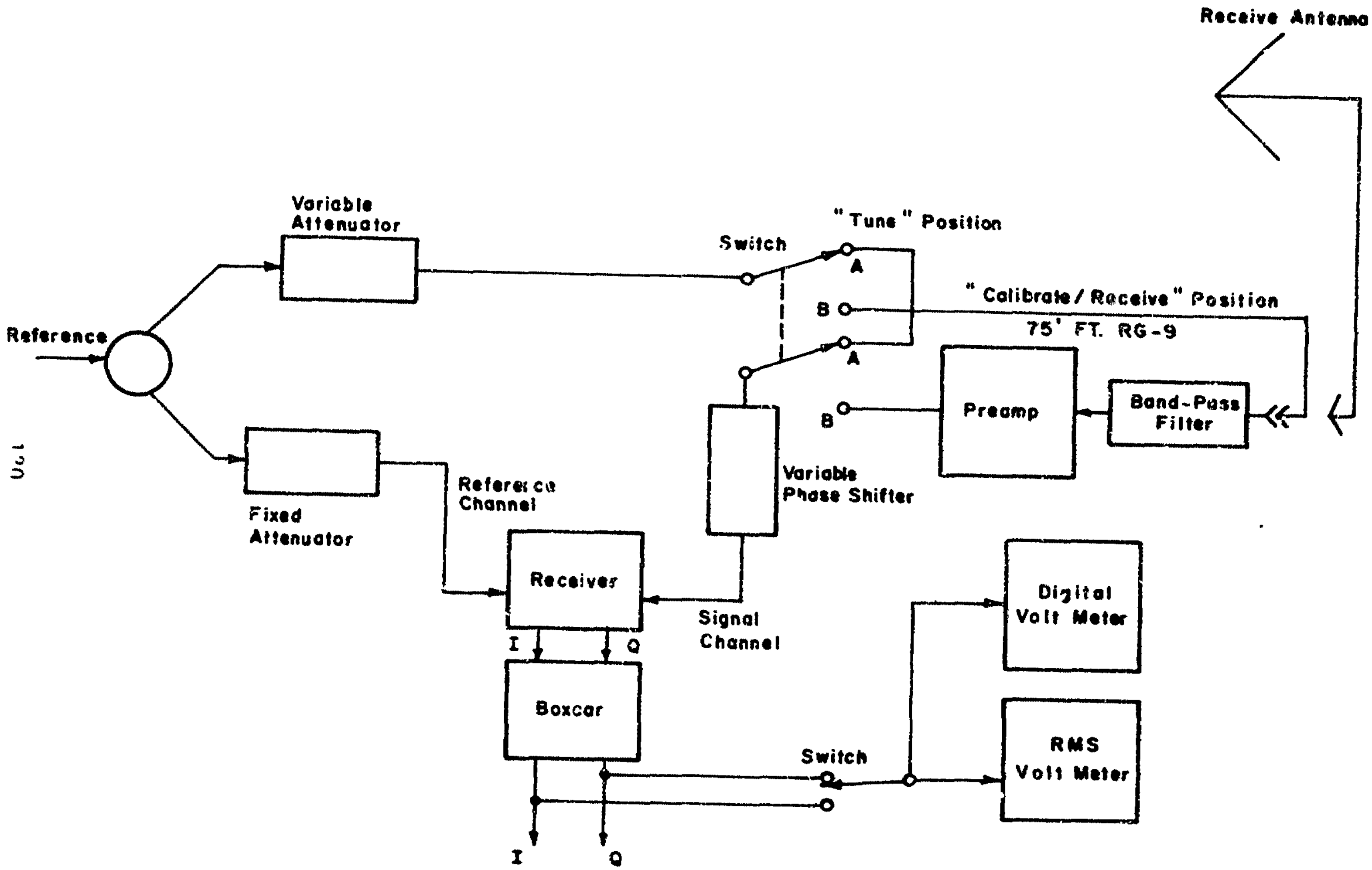

Fig. 69 RECEIVER "TUNE" AND "CALIBRATE / RECEIVE" POSITIONS

Thus, -100 dBm appears to be an acceptable compromise between the extremes. From the above measurements, H can be calculated as a function of IF gain setting, since

$$H = \frac{\sqrt{P_R}}{V_o}$$

where $P_R = 10^{-13}$ watts and V_o is read from the digital voltmeter. At this point in the calibration procedure, H versus the IF gain setting is available for calculations of K.

It can be seen from equation (13) above that the terms L_{RC}, L_{RA}, L_{TA}, L_{TC}, and P_{TO} still have to be found so that K may be calculated. The L_{RC} and L_{TC} are found by measuring the insertion loss between the points shown in Figure 68. Of necessity, L_{RC} is measured at the five third harmonic frequencies, while L_{TC} is measured at the five fundamentals.

L_{TA} and L_{RA} are the transmit and receive path losses, respectively. Their measurements can be divided into two categories. The first category pertains to those measurements performed between the fifty foot tower and the road. This is to be used for the testing of large targets. The other category pertains to measurements performed on the ground antennas which are to be used for the small target tests.

Due to the size difference between the large and small targets to be tested, the meaning of L_{TA} differs slightly for the two cases. From the previous definitions, L_{TA} relates the power fed to the transmitting antenna to the fundamental power density at the target location. For the small targets, the power density is relatively constant over the target extent; therefore the power density in question

is that which excites the target. For the large targets, multipath from the ground results in standing waves of field intensity over the vertical extent of the target. A unique single-ended power density at the target will not exist for any of the large target tests. A convention was established for large target antenna calibrations which permits meaningful utilization of the data. This is accomplished by defining the power density used in the large target calibration factor to mean the power density of the direct wave component of the field, i.e., the power density which would exist in the absence of the ground. Determination of this is made by measuring the field intensity standing wave maxima and minima and calculating the necessary direct-wave component. Similar considerations apply for receive path loss calibrations for large targets.

The method of measurement is to use a signal generator to feed the antenna in question. Then, a receiver and calibrated receive antenna are used to measure the "free space" signal. After that is done, the two antennas are disconnected and the signal generator is fed directly into the receiver. The signal generator is then attenuated enough from the signal it fed into the antenna so that the signal level at the receiver input is the same as when receiving with the calibrated antenna; i.e., this method is signal substitution. The difference in the two signal generator levels, after taking the calibrated antenna into account, is the path loss.

L_{RA}, the receive path loss, is measured essentially in the same manner. There are, of course, differences in the actual frequencies used and differences in the calibrated antennas used.

Now all that is required to find K is P_{T01}, the transmitter peak pulse power. Since the transmit path losses are not equal at all frequencies, only one frequency can be used to transmit the full 5 kW that is available at the transmitter. This frequency will be the one with the highest transmit path loss. This determines the highest power density at the target that will be available at all frequencies. Once this is calculated, then the other transmitted power levels are calculated to give this power density. These power levels are, of course, less than 5 kW because the transmit path losses are smaller than the maximum mentioned above.

Thus, at this point, K may be calculated and plotted versus IF dial setting for each test frequency.

6.4.3 Decreasing Radiated Power in 10 dB Steps

If transmitter power is reduced 10 dB, then from equation (13):

$$K_{10dB} = H \sqrt{\frac{L_{RC}\, L_{RA}\, L_{TA}\, L_{TC}}{\frac{P_{TO}}{10}}} = \sqrt{10}K \qquad (14)$$

Table XI below shows the correction factor to use when transmitter power is decreased in 10 dB increments:

	TRANSMITTER POWER			
	5 kW (0 dB)	500 W (-10 dB)	50 W (-20 dB)	5 W (-30 dB)
Multiply K by This Number	1	10	10	10 10

TABLE XI K-FACTOR MULTIPLIERS

6.4.4 K-Factor Summary

Table XII below lists the K-factor values as functions of H. These values are derived from path losses and transmission line losses and are normally considered constant with time.

K_1 is the tower transmitting antenna and K_4 is the ground transmitting antenna.

6.4.5 Actual Calibration Numbers

Tables XIII through XXV list the actual calibration numbers used from September 25, 1973. Periodic checks between that date and early December 1973, showed negligible change.

Calibration charts were used early in the program but were abandoned in favor of the tables where the receiver IF gain would be deliberately set at a number listed on the table and the K-factor would be read directly from it.

Tower antenna K-factors are provided for the standard 20 W/m^2 power density at the large targets; however, for the ground antennas, the K-factors have been calculated for the four power densities used in small target testing so that, after switching high-power 10 dB attenuators in the transmitter output, the "New" K-factor can be read directly from the table.

K-FACTORS

Receiving Frequency (MHz)	Tower Dish Antenna (K_2)	Tower Receiving LPA (K_3)	Ground Dish Antenna (K_5)	Ground Receiving LPA (K_6)
690.0	-	$K_3=H(4.11 \times 10^2)$	-	$K_6=H(2.38 \times 10)$
923.1	-	$K_3=H(7.14 \times 10^2)$	-	$K_6=H(2.14 \times 10)$
1308.3	$K_2=H(6.78 \times 10^2)$	$K_3=H(1.90 \times 10^3)$	$K_5=H(9.47 \times 10)$	-
1652.7	$K_2=H(3.80 \times 10^2)$	$K_3=H(1.70 \times 10^3)$	$K_5=H(6.25 \times 10)$	-
2211.0	$K_2=H(5.63 \times 10^2)$	$K_3=H(2.20 \times 10^3)$	$K_5=H(3.16 \times 10)$	-

TABLE XII K-FACTORS AS A FUNCTION OF H

IF DIAL	K_2
188	2103
200	1303
220	6204
240	3504
260	2254
280	1504
300	1104
320	8405
340	6705
360	5605
380	4755
400	4185
420	3705
440	3355
460	3105
480	2905
500	2805

TABLE XIII K_2 AT 1308.3 MHz

IF DIAL	K_2
180	9004
190	6404
200	4504
210	3204
220	2304
230	1704
240	1274
250	9605
260	7405
270	5805
280	4605
290	3705
300	3005
310	2525
320	2155
330	1875
340	1665
350	1505
360	1355
370	1255
380	1165
390	1105
400	1045
410	1005

TABLE XIV K_2 AT 1652.7 MHz

IF DIAL	K_2
90	4603
100	3453
110	2603
120	2003
130	1503
140	1103
150	8504
160	6354
170	4804
180	3604
190	2754
200	2004
210	1504
220	1104
230	8005
240	6005

TABLE XV K_2 AT 2211.0 MHz

IF DIAL	K_3
200	1833
220	9004
240	4204
260	2204
280	1304
300	8505
320	6505
340	5205
360	4405
380	3805
400	3355
420	3055
440	2805
460	2675
480	2525
500	2405
520	2325
540	2275
560	2205
580	2175
600	2145
620	2105
640	2085
660	2045
680	2005
700	1995
720	1965
740	1925
760	1905
780	1885
800	1855
820	1825
840	1805
860	1795
880	1765
900	1750

TABLE XVI K_3 AT 690.0 MHz

IF DIAL	K_3
200	1133
220	6504
240	3504
260	2004
280	1204
300	7505
320	5505
340	4205
360	3505
380	3105
400	2805
420	2525
440	2345
460	2205
480	2065
500	1965
520	1885
540	1805
560	1765
580	1715
600	1695
620	1665
640	1625
660	1605
680	1595
700	1565
720	1525
740	1505
760	1485
780	1455

TABLE XVII K_3 AT 923.1 MHz

IF DIAL	K_3
188	5903
200	3783
220	1833
240	1003
260	6404
280	4304
300	3004
320	2304
340	1854
360	1524
380	1304
400	1154
420	1014
440	9205
460	8505
480	7905
500	7555

TABLE XVIII K_3 AT 1308.3 MHz

IF DIAL	K_3
180	4003
190	2803
200	2003
210	1403
220	1003
230	7404
240	5404
250	4204
260	3204
270	2504
280	2004
290	1654
300	1364
310	1154
320	1004
330	8605
340	7605
350	7005
360	6405
370	5805
380	5505
390	5205
400	4825
410	4605

TABLE XIX K_3 AT 1652.7 MHz

IF DIAL	K_3
90	1802
100	1352
110	1022
120	8003
130	6003
140	4553
150	3903
160	2503
170	1903
180	1453
190	1073
200	8004
210	6004
220	4404
230	3504
240	2403

TABLE XX K_3 AT 2211.0 MHz

IF DIAL	K_5 AT $20W/m^2$	K_5 AT $2W/m^2$	K_5 AT $0.2W/m^2$	K_5 AT $0.02m^2$
188	2944	9284	2943	9283
200	1754	5504	1753	5503
220	8205	2674	8204	2673
240	4705	1484	4704	1483
260	2905	9115	2904	9114
280	1955	6135	1954	6134
300	1425	4465	1424	4464
320	1105	3455	1104	3454
340	9006	2825	9005	2824
360	7506	2355	7505	2354
380	6456	2035	6455	2034
400	5706	1785	5705	1784
420	5006	1575	5005	1574
440	4606	1445	4605	1444
460	4306	1355	4305	1354
480	4106	1295	4105	1294
500	3916	1235	3915	1234

TABLE XXI K_5 AT 1308.3 MHz

IF DIAL	K_5 AT $20W/m^2$	K_5 AT $2W/m^2$	K_5 AT $0.2W/m^2$	K_5 AT $0.02m^2$
180	1404	4404	1403	4403
190	1004	3144	1003	3143
200	7105	2234	7104	2233
210	5205	1604	5204	1603
220	3705	1164	3704	1163
230	2705	8495	2704	8494
240	2205	6915	2204	6914
250	1655	5205	1654	5204
260	1305	4085	1304	4084
270	1005	3145	1004	3144
280	8006	2605	8005	2604
290	6306	1975	6305	1974
300	5006	1565	5005	1564
310	4206	1325	4205	1324
320	3606	1135	3605	1134
330	3106	9506	3105	9505
340	2756	8686	2755	8685
350	2506	7866	2505	7865
360	2306	7246	2305	7245
370	2156	6776	2155	6775
380	2006	6286	2005	6785
390	1906	5996	1905	5995
400	1786	5606	1785	5605
410	1706	5356	1705	5355

TABLE XXII K_5 AT 1652.7 MHz

IF DIAL	K_5 AT $20W/m^2$	K_5 AT $2W/m^2$	K_5 AT $0.2W/m^2$	K_5 AT $0.02W/m^2$
90	2704	8474	2703	8473
100	2004	6284	2003	6283
110	1504	4704	1503	4703
120	1114	3484	1113	3483
130	8505	2664	8504	2663
140	6505	2034	6504	2033
150	5005	1574	5004	1573
160	3755	1184	3754	1183
170	2755	8655	2754	8654
180	2105	6605	2104	6604
190	1555	4875	1554	4874
200	1155	3605	1154	3604
210	8606	2695	8605	2694
220	6406	2015	6405	2014
230	4806	1515	4805	1514
240	3406	1075	3405	1074

TABLE XXIII K_5 AT 2211.0 MHz

IF DIAL	K_6 AT $20W/m^2$	K_6 AT $2W/m^2$	K_6 AT $0.2W/m^2$	K_6 AT $0.02W/m^2$
200	8005	2524	8004	2523
220	3505	1014	3504	1013
240	1955	6115	1954	6114
260	1205	3765	1204	3764
280	8006	2525	8005	2524
300	5606	1755	5605	1754
320	4206	1325	4205	1324
340	3406	1065	3405	1064
360	2806	8806	2805	8805
380	2406	7556	2405	7555
400	2106	6606	2105	6605
420	1866	5856	1865	5855
440	1696	5316	1695	5315
460	1576	4946	1575	4945
480	1496	4686	1495	4685
500	1406	4406	1405	4405
520	1356	4246	1355	4245
540	1306	4086	1305	4085
560	1276	3996	1275	3995
580	1246	3896	1245	3895
600	1226	3836	1225	3835
620	1216	3806	1215	3805
640	1206	3776	1205	3775
660	1196	3746	1195	3745

TABLE XXIV K_6 AT 690.0 MHz

IF DIAL	K_6 AT $20W/m^2$	K_6 AT $2W/m^2$	K_6 AT $0.2W/m^2$	K_6 AT 0.02W/m2
200	3505	1104	3504	1103
220	2005	6285	2004	6284
240	1055	3305	1054	3304
260	6006	1875	6005	1874
280	3506	1105	3505	1104
300	2406	7556	2405	7555
320	1706	5356	1705	5355
340	1306	4096	1305	4095
360	1056	3306	1055	3305
380	9207	2876	9206	2875
400	8207	2616	8206	2615
420	7607	2386	7606	2385
440	7007	2196	7006	2195
460	6577	2066	6576	2065
480	6207	1946	6206	1945
500	6007	1876	6006	1875
520	5707	1786	5706	1785
540	5557	1746	5556	1745
560	5407	1696	5406	1695
580	5227	1636	5226	1635
600	5107	1596	5106	1595
620	5007	1566	5006	1565
640	4907	1546	4906	1545
660	4807	1506	4806	1505
680	4707	1476	4706	1475
700	4607	1446	4606	1445
720	4557	1426	4556	1425
740	4427	1386	4426	1385
760	4407	1376	4406	1375
780	4307	1346	4306	1345

TABLE XXV K_6 AT 923.1 MHz

6.5 Data System

Refer to separate instructions, provided by the manufacturers, for long-term maintenance on the CPU, Teletype Unit, Reader/Punch and Tape Transport.

6.5.1 Data System Calibration

Fig. 70 shows the test set-up for checking the data system calibration. Calibration should be performed periodically or when malfunctioning is suspected.

6.5.2 A/D Test Routine Operation

Test periodically per Table XXVI.

6.5.3 Reader Test Routine Operation

Test periodically per Table XXVII.

6.5.4 Program Errors

Check Table XXVIII as required.

6.5.5 Data System Faults

Test per Table XXIX.

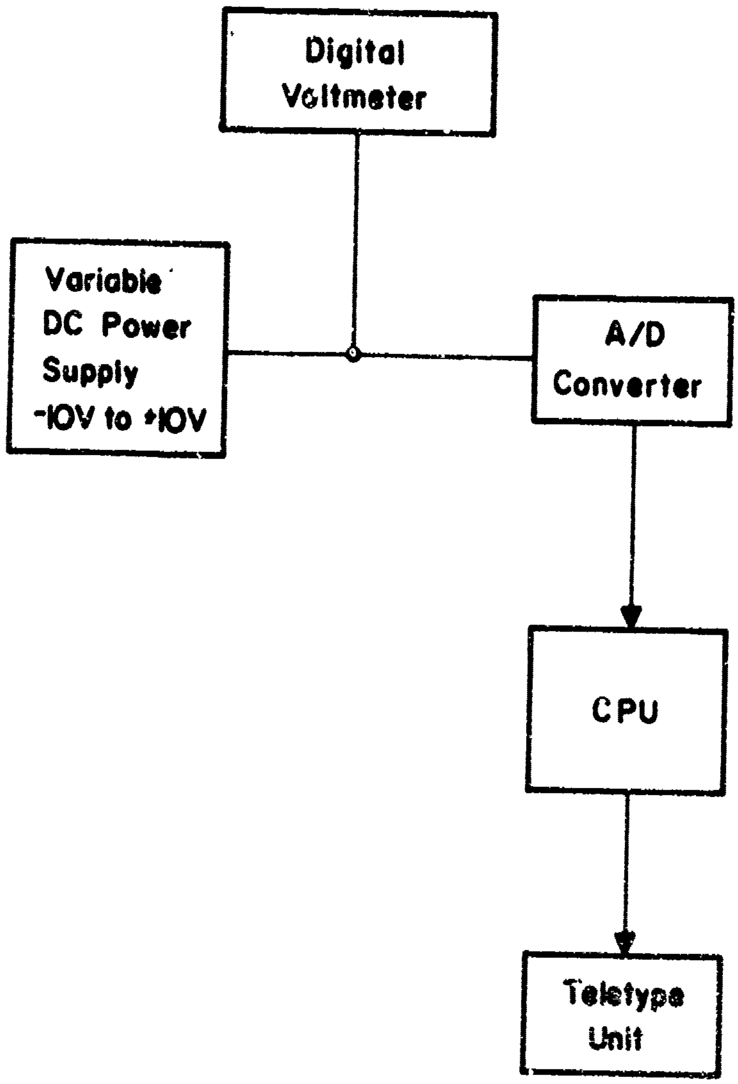

Fig. 70 TEST SET-UP FOR CALIBRATION

TABLE XXVI - A/D TEST ROUTINE OPERATION

ACTION	SYSTEM RESPONSE	DISCUSSION
1. Set CPU switches to 117777.	A. Tape loads into CPU.	A. Proceed to 3.
2. Depress Reset, Start.	B. Tape does not load.	B. See Table V - Program Load. Procedure
3. Set CPU switches to 274.	A. CPU halts @ 315.	A. Depress AC0 Examine ; output = Last MUX Channel # Depress AC1 Examine ; output = Current MUX Channel # Depress AC2 Examine ; output = Converted value Depress AC3 Examine ; output = Device Code 21
	B. CPU Runs.	B. Depress Stop. CPU ADDRESS @ 302 or 303 The "done" FF in the interface is not being set, check the interface hardware.
		C. Depress Stop CPU ADDRESS @ 304. Check contents of Location 1 - should be 310. If not, reload A/D test routine. If address is 310, depress continue. If ION indicator is not on, trouble is in the CPU.

TABLE XXVII - READER TEST ROUTINE OPERATION

ACTION	SYSTEM RESPONSE	DISCUSSION
If the reader does not function or reads improperly, the teletype reader must be used to enter the test program.		
1. Change the bootstrap loader		Using DEBUG or the CPU Switches, change the following locations: 17760/063610 17762/060510 07770/060110
2. Load Binary Block Loader into the Teletype reader		
3. Set CPU Switches to 017770.		
4. Depress Reset, Start.	Tape read & stops at the end.	If not, check the bootstrap loader with its listing on the program card.
5. Set CPU switches to 017777.		
6. Load Reader Test Routine into Teletype Reader.		
7. Depress Reset, Start	Tape read & stops at the end.	
8. Reload Program into reader.		
9. Set CPU switches to 274.		

TABLE XXVII - READER TEST ROUTINE OPERATION (Cont'd)

ACTION	SYSTEM RESPONSE	DISCUSSION
10. Depress Reset, Start.	Tape moves 1 character position, CPU stops @ 311	Depress ACC3 examine ACC3 = 12 Depress ACC1 examine ACC1 = Tape contents Hole = 1 No Hole = 0
11. Depress Continue	Tape moves 1 character position, CPU stops @ 311	Continue this process until sufficient characters have been read to indicate if any reader positions are bad. If tape does not advance, check program. If program is O.K., check the feed hole output line on the reader control card while alternately covering and illuminating the feed hole photo detector. If the output does not swing between 0-4V, the problem is a faulty reader block.

TABLE XXVIII - MERDC PROGRAM ERROR SUMMARY

COMMAND	TELETYPE OUTPUT	REMEDY
Wrong input	No Such Command.	Type correct command.
	Command Format Error.	Type ⤸ carriage return after command character pair.
BT	Not at LD. PT.	BOT gap can be written only at the beginning of tape.
	No Write Ring.	Remove tape and insert file ptotect. ring.
IT	Format Error.	Illegal control character typed after character string. See trailer command summary.
EF	T.D. OFF Line	Depress "On Line" switch on tape drive.
	NO. EOF WRITTEN	Check mag tape interface.
BS	Operator Error No Tape Written	
WD	Tape Drive Not Ready.	Depress On Line switch on tape drive.
	Tape Interface Busy	Hardware problem - if tape drive moves tape continuously, degauss heads.
	Tape Drive Not Ready.	Depress On Line switch on tape drive.
	Tape ERROR STATUS = XXXXXX	Check page 4-5 of NOVA manual. Copy in the mag tape section.
	HALT @ INRS + 33_8	Fatal error data buffers loaded wrong. Check INRS program and A/D hardware interface.
	HALT @ COMPT + 435_8	No samples in this channel. Average absolute output in ERROR. Depress Continue.

TABLE XXIX - TROUBLE SHOOTING GUIDE

SYMPTOM	PROBABLE CAUSE	REMEDY
1. Teletype does not echo print.	Computer not in MERDC operating program.	1. Set CPU switches to 400.
		2. Depress Reset, Start (jump to DEBUG).
		3. If teletype does not type accumulator values, reload program.
		4. Type 0/ The address typed should lie within the EXEC program.
		5. Type 1/ The address typed should be INRS of the memory map listing.
		6. If the above addresses are not correct, restart program at the EXRS entry point. If the above problem continued, reload program.
2. System does not respond to commands.	1. Teletype off line.	7. Place teletype on line.
	2. Computer not in EXEC program.	8. Type illegal command - if system does respond with "No Such Command", perform Steps 1-5 above. If the address in location "0" lies in the CKDAT program, check interface power supplies.

TABLE XXIX - TROUBLE SHOOTING GUIDE (Cont'd)

SYMPTOM	PROBABLE CAUSE	REMEDY
		If interface power supplies are operating correctly, restart program at EXRCS, input command "IT". If system does not respond to "IT" command, reload MERDC program. If system responds to "IT" command, return program control to EXEC via input Cntl E. Input ST command. If data summary is not typed within 30 sec., problem is within the A/D test routine.
3. Output data summary does not agree with observed scope values.	A/D converter problem.	Refer to A/D test program.
4. Frequent parity errors.	Tape transport heads dirty or need degaussing.	Clean and degauss heads.
5. Tape transport runs continuously RS or RL command.	Dirty or magnetized tape head.	Clean and degauss tape head. Then restart program.
	Problem persists.	Place standard output level tape in tape drive and monitor test points 402-902 on the data electronics board (left wall) within the tape drive while operating the transport using the mag "Tape Test Program".

TABLE XXIX - TROUBLE SHOOTING GUIDE (Cont'd)

SYMPTOM	PROBABLE CAUSE	REMEDY
		Using DEBUG, set up the program to space forward. 100 records via the following changes: 346/0 ; Read 351/7700 347/0 ; Read 352/7700 350/0 ; Read 353/7700 360/100000 ; Stop on error 356/1000 ; wait time 274R ; Start program @ 274
		An output voltage of approximately 12V P-P should exist on the above test points. If the above measurements could not be made within the run time, replace 346-350 0's with 40's to back space and continue measurements. If not, a problem exists in the tape drive read electronics; check Wang manual.
		If tape drive functions properly in the above test, space to the end of the records and change to the write mode by the following: 346/50) 351/7770) 347/50);write 356/7770) 10 records 350/50) 353/7770) 13717/37477 13723/37477 13720/37477 13724/37477 13721/37477 13725/37477 13722/37477 13726/37477

TABLE XXIX - TROUBLE SHOOTING GUIDE (Cont'd)

SYMPTOM	PROBABLE CAUSE	REMEDY
		274R the tape drive should write 10 character records and output test points 402 to 902 should be ~ 12V P-P. If the drive does not function properly, the problem is in the write electronics. If the tape drive runs continuously in both of the above tests, the problem lies in the tape interface.
6. Data can be read from Wang transport but not on CDC 6600.	BT command not given to write BOT gap after BOT marker.	Write BOT gap on all tapes.
	Record density not at 800 BPI.	Check density with master skew tape. NOTE! Skew tape does not contain records and thus tape will move continuously. Using DEBUG, set up the mag tape test, as follows: 346/0) 351/0) 347/0) Read 352/0) Large Record 350/0) 353/0) 274R Monitor test point TP3 on tape drive servo amplifier board (see pp. VI-85 in Wang Manual); period should be 27.7 μ sec.

TABLE XXIX - TROUBLE SHOOTING GUIDE (Cont'd)

SYMPTOM	PROBABLE CAUSE	REMEDY
	Inter-record gap (IRG) length wrong.	Load a scratch tape on drive using DEBUG, setup the mag tape test routine using DEBUG as follows: 346/50) 351/7770) 347/50) Write. 352/7770) 10 Records 350/50) 353/7770) 360/100000 356/2000 274R
		Monitor test point TP-5, on the tape drive control-logic board. The start/stop ramps should be consistent with the times specified on pp. VI-36 & 37 of the Wang manual.
7. Computer runs but does not output data summary.	A/D interface not "done"	1. Depress STOP, program counter contents should lie in CKDAT program. If above is true, restart program from EXRCS. If tape was written, input command BS and repeat experiment in progress when fault occurred.
		If this problem persists, the A/D converter or interface has a problem. Read in A/D test routine and check out converter and interface.

7. PARTS LIST

7.1 Transmitting System

The parts shown below are items added since publication of the instruction manuals for the transmitter.

Quantity	Part Number	Description	Manufacturer
1	S10063	Crystal Source 230 MHz	Spectra
1	S10064	Crystal Source 307 MHz	Spectra
1	S10065	Crystal Source 436.1 MHz	Spectra
1	S10066	Crystal Source 550 MHz	Spectra
1	S10067	Crystal Source 737 MHz	Spectra
6	A6NT220	Power Supply, 6.3 VDC, 2.2 A	Acopian
2	A6NT300	Power Supply, 6.3 VDC, 3.0 A	Acopian
2	3020A	20 dB Coupler	Narda
1	TLC430-7EE1	Low Pass Filter	Telonic
1	TLC750-7EE1	Low Pass Filter	Telonic
2	8135	Dummy Load	Bird
2	771-10	Attenuator, 10 dB	Narda
1	AF6	Attenuator, 6 dB	Microlab
1	--	Detector	AEL
2	7422	Switch, Coaxial, SPDT	Bird
1	319-111-141	Switch, Coaxial	Amphenol
1	6521A	0-1 kV Power Supply	Hewlett-Packard
1	6522A	0-2 kV Power Supply	Hewlett-Packard
1	6525A	0-4 kV Power Supply	Hewlett-Packard
Misc.	RG-9 B/U, RG-55 B/U	Coaxial Cable and Connectors	

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7.2 Receiving System

Only one major substitution has been made in the receiver. The original local oscillator in the 2-6 GHz head has been replaced by a Spectra Model S10068 crystal-controlled source having an output frequency of 2371 MHz.

The receiver itself was manufactured by the Astro Communications Laboratory and is their Model SR-801 Coherent Receiver. It is provided with the SH-820P Tuner (250-500 MHz) the SH-821P Tuner (500-1000 MHz), the SH-822P Tuner (1-2 GHz), and the SH-823P Tuner (2-4 GHz plus 4-6 GHz).

7.2.1 Boxcar Unit (See Fig. 23)

Item	Part Number	Description	Manufacturer
A-1	SHM-2	Sample/Hold	Datel Systems
A-2	SHM-1	Sample/Hold	Datel Systems
A-3	3266/12C	Operational Amp.	Burr-Brown
C-1		Capacitor, 0.005 μF	
C-2		Capacitor, 0.01 μF, Disc	
C-3		Capacitor, 0.01 μF, Disc	
C-4		Capacitor, 0.01 μF, Disc	
C-5		Capacitor, 0.01 μF, Disc	
C-6		Capacitor, 20 pF Silver Mica	
C-7		Capacitor, 0.1 μF	
C-8		Capacitor, 1000 pF Silver Mica	
C-9		Capacitor, 0.1 μF	
C-10		Capacitor, 0.1 μF	
C-11		Capacitor, 120 pF Silver Mica	

Item	Part Number	Description	Manufacturer
FL-1			
J-1			
J-2			
J-3			
J-4			
1C1	SN54121N	Integrated Circuit	
1C-2	SN54121N	Integrated Circuit	
1C-3	SN54121N	Integrated Circuit	
J-1			
J-2			
J-3			
J-4			
L-1		Inductor	
PS-1	BPM 15/200	15 VDC Power Supply	Datel Systems
R-1		Resistor, Composition, 100 ohms, 5%, 1/2 W	
R-2		Resistor, Composition, 2k ohms, 5%, 1/2 W	
R-3		Resistor, Composition, 100 ohms, 5%, 1/2 W	
R-4		Resistor, Variable, 25k ohms	
R-5		Resistor, Composition, 25k ohms	
R-6		Resistor, Composition, 2k ohms, 5%, 1/2 W	
R-7		Resistor, Composition, 1k ohm, 5%, 1/2 W	
R-8		Resistor, Variable, 10k ohms	
R-9		Resistor, Composition, 7.5k ohms, 5%, 1/2 W	
R-10		Resistor, Composition, 4.7k ohms, 5%, 1/2 W	

Item	Part Number	Description	Manufacturer
R-11		Resistor, Variable, 20k ohms	
R-12		Resistor, Variable, 10k ohms	
R-13		Resistor, Composition, 2k ohms, 5%, 1/2 W	

7.3 Antenna System and Receiving Filters

7.3.1 Antennas

Item	Part Number	Description	Manufacturer
1	APN-109B*	Transmitting LPA	AEL
2	4133-L1-N	Receiving Dish, 36"	ACA
3	2302-L1-N	Receiving LPA	ACA
4	2305-L1-N	Transmitting LPA	ACA
5	AT-112	Receiving Dish, 18"	Singer, Metrics Div.
6	2302-L1-N	Receiving LPA	ACA
FL-1	TBC690-78-9EE1	Filter, Receiving, 690 MHz	Telonic
FL-2	FBT/20-923/50-7/50-1A/1A	Filter. Receiving 923 MHz	Cir-Q-Tel
FL-3	TBA1305-230-6EE	Filter Receiving 1308 MHz	Telonic
FL-4	FBT/20-1652/80-8/50-1A/1A	Filter Receiving 1652 MHz	Cir-Q-Tel
FL-5	FBT/5-2211/130-8/50-1A/1A	Filter Receiving 2211 MHz	Cir-Q-Tel
--	----	Tower	IITRI/Hawkins

*Rear Elements Removed by IITRI

7.3.2 Pre-Amplifier Box (See Fig. 72)

Item	Part Number	Description	Manufacturer
A1	SC2510ST	200-1000 MHz Pre-Amplifier	Scientific Communications
A2	L1020HN	1-2 GHz Pre-Amplifier	E&M Labs.
A3	WJ-343-8	2-6 GHz Pre-Amplifier	Watkins-Johnson
AT1	33300C-000	Variable Attenuator	Hewlett-Packard
AT2	771-20	20 dB Attenuator	Narda
B1	4506	Blower	Pamotor
F1	3AG	Fuse, 1/4 A, Slo-Blo	Littelfuse
F2	3AG	Fuse, 1/10 A Slo-Blo	Littelfuse
F3	3AG	Fuse. 1 A, Slo-Blo	Littelfuse
J1		Power Connector	
J2*		Jack, Type N	
J3*		Jack, Type N	
PS1	3B18-.15	18 VDC Power Supply	Powertec
PS2	3B15-.2	15 VDC Power Supply	Powertec
S1*	744	1P3T Coaxial Switch	Bird
S2*	7422	SPDT Coaxial Switch	Bird
S3*	7422	SPDT Coaxial Switch	Bird
S4		1P4T Wafer Switch	
S5		SPST Toggle Switch	

*Gold-Plated by IITRI

Item	Part Number	Description	Manufacturer
TB1		Terminal Board	
TB2		Terminal Board	
--	---	Misc. RF Connectors	---
--	---	Misc. RF Cabling	---

7.3.3 Attenuator Control Box (Located Inside Van) (See Fig. 73)

Item	Part Number	Description	Manufacturer
DS1	327	12 V Lamp	Chicago
DS2	327	12 V Lamp	Chicago
DS3	327	12 V Lamp	Chicago
TB1		Terminal Board	
TB2		Terminal Board	
S1	8835K4	DPDT Switch	Cutler-Hammer
S2	8835K4	DPDT Switch	Cutler-Hammer
S3	8835K4	DPDT Switch	Cutler-Hammer
	177-8430-09-503 (3 pieces)	Lamp Holder	Dialco
	177-0934-003 (3 pieces)	Blue Lens Cap	Dialco

7.4 Primary Power System

Quantity	Part Number	Description	Manufacturer
1	KD-20	Diesel Generator	Kurz-Root
1	214A156	Under Frequency Monitor	ASCO
1		Over Voltage Monitor	
1		DPDT Relay	
1		DPST Relay	
1		Hold Control Relay	
1	AR-1031	Receptacle	Crouse-Hinds
1	TL612RH (Mod. 1)	Load Center	General Electric
1		2 Pole Breaker, 40 A	
1		2 Pole Breaker, 30 A	
2		1 Pole Breaker, 20 A	
1		Switch, Toggle	
1		Momentary Switch	
3	NE-51	Neon Lamp	
3		Lampholder	
1	30-FG-10	Frequency Meter	JBT
1	D1-926	AC Voltmeter	Calectro
3	NFR 124-1	Line Filter	Cornell-Dubilier
3	NFR-112-1A	30 A Filter for Transmitter Cabinet	Cornell-Dubilier

Quantity	Part Number	Description	Manufacturer
4	NFR-102-6A	10 A Filter for Transmitter Cabinet	Cornell-Dubilier
3	NFR-103-5A	50 A Filter	Cornell-Dubilier
5	NFR-102-6A	10 A Filter	Cornell-Dubilier
3	NFR-112-1A	30 A Filter	Cornell-Dubilier
1	EQ12A	Load Center	I.T.E.
1	SU-12	Cover for Above Load Center	I.T.E.
3	QP2-B030	2 Pole Breaker	I.T.E.
6	QP1-B020	1 Pole Breaker	I.T.E.

7.5 Air Conditioning System

Item	Part Number	Description	Manufacturer
	AF010H0K	Fan Unit	Westinghouse
	HL030C0W	Compressor	Westinghouse
	Special	10 kW Heater	Brasch
	FPAC1-240-12	SCR Controller	Loyola
	TS5191	Room Thermostat	Crydom (Barber-Colman)
	Special	Amplifier, Signal	Electrix
		Transformer	
		Relay, 115 VAC	
		Relay, 24 VAC	
		Relay, 24 VAC	
		Terminal Board	

7.6 Exterior Cabling (See Fig. 74)

Item	Part Number	Description	Manufacturer
A-1	UG-29A/U	Adapter	Amphenol
A-2	UG-29A/U	Adapter	Amphenol
A-3	UG-29A/U	Adapter	Amphenol
A-4	UG-29A/U	Adapter	Amphenol
A-5	UG-27C/U	Adapter	Amphenol
A-6	UG-29A/U	Adapter	Amphenol
W-1		75 ft. Power Cable*	IITRI
W-2		75 ft. HJ5-50 Heliax plus Two 75 AW Plugs and 3500 Pressure Gauge plus Gas Fittings	Andrew

Item	Part Number	Description	Manufacturer
W-3		75 ft. HJ5-50 Heliax plus two 75 AW Plugs 3500 Pressure Gauge plus Gas Fittings	Andrews
W-4		75 ft. RG-9B/U with Type N Male Plugs (UG-1185/U)	IITRI
W-5		One ft. RG-9B/U with Type N Male Plugs (UG-1185/U)	IITRI
W-6		One ft. RG-9B/U with Type N Male Plugs (UG-1185/U)	IITRI
W-7		One ft. RG-9B/U with Type N Male Plugs (UG-1185/U)	IITRI
W-8		2 ft. RG-9B/U with Type N Male Plugs (UG-1185/U)	IITRI
W-9		50 ft. HJ5-50 Heliax plus Two 75 AW Plugs and 3500 Pressure Gauge plus Gas Fittings	Andrew
W-10		9-1/2 ft. RG-9B/U with Type N Male Plugs (UG-1185/U)	IITRI
W-11		50 ft. HJ5-50 Heliax plus Two 75 AW Plugs and 3500 Pressure Gauge plus Gas Fittings	Andrew
W-12		7-1/2 ft. No. FSJ4-50 Heliax Plus one 36723A and one 40229 Connectors	Andrew
W-13		18-1/2 ft. HJ4-50 Heliax Plus two 74W Plugs and 3500 Pressure Gauge plus Gas Fittings	Andrew

Item	Part Number	Description	Manufacturer
W-14	Type W	35 ft. HJ4-50 Heliax plus Two 74W Plugs and 3500 Pressure Gauge plus Gas Fittings	Andrew
W-15		24 ft. HJ24-50 Heliax plus One 74W Plug and One 74N Jack plus 3500 Pressure Gauge and Gas Fittings	Andrew
W-16	Type W	50 ft. OKOCORD Three-Conductor No. 4 Stranded Wire with Crouse-Hinds APJ10355 Connector on One End	Okonite (Wire Only)
W-17	THW	Three 175 ft. Lengths No. 4 Stranded Wire Connected to W-16 by IITRI	Phelps-Dodge

*Cable W-1 consists of 75 ft. 20-gauge, 19 conductor type 16878 BN multi-conductor cable (obtained from Baron Wire Co., 4300 West Montrose, Chicago, Illinois 60625) plus two MS3126E-14-19S Connectors.

7.7 Miscellaneous Parts

Quantity	Part Number	Description	Manufacturer
1	D500	Truck	Dodge
1	Special	Body	Erlinder Mfg.
1	RW-530-33	Bench	Hallowell
4	3000	Lock	Reb Steel
1 Pr.	6122-30	End Pieces for Bench	Reb Steel
1	6416-4	Back Board for Bench	Reb Steel
1	6025-4	Wiremold for Bench	Reb Steel
6	C3125-T10	Generator Shockmounts	Barry Controls

Quantity	Part Number	Description	Manufacturer
24	C2090-T6	Shockmounts	Barry Controls
1	C25962	RF1 Cabinet for Transmitter	Zero Mfg. Co.
3	DRA-7B-25-LK	Drawers for RF1 Cabinet	Emcor-Ingersoll
1	IE #7	Non RF1 Cabinet Frame, 2 Side Panels, 1 Rear Door, 1 Base	Emcor-Ingersoll
2	IE #8	Non RF1 Cabinet Frame, 1 Rear Door, 1 Base	Emcor-Ingersoll
6	PN21	Top and Bottom Panels	Emcor-Ingersoll
14	SH25A	Shelves	Emcor-Ingersoll
3	PMA-78A	Panel Mounting Angles	Emcor-Ingersoll
200	AHWX-092-003219	Locking Nuts	Emcor-Ingersoll
200	HW1076	Nylon Glides	Emcor-Ingersoll
200	HW104	Screws	Emcor-Ingersoll
36	SL-1219-2	Fixed Pin	Shur-Lok
36	SL-1243-E-2	Hooks	Shur-Lok
36	SL-1213-2	Clamp Assembly	Shur-Lok
1 Pr.	3[illegible]1-0086-00	Mountings for Oscilloscope	Tektronix
13 Pr.	CTD-124-E94	Chassis Slides and Extensions	Zero Mfg. Co.
1	1469-1224	Wall Cabinet	Reb Steel
1	SK6224-W1 (Less Alum-[illegible]m Frame)	Shield-Vu EMI Window	Metex
5	5BH701	Bench Lights	Fostoria-Wakefield

Quantity	Part Number	Description	Manufacturer
5	Series H	Light Shields	Fostoria-Wakefield
23 ft.	97-440	Finger Stock for Van Door	Instrument Specialities
1	CHS50	Public Address Amplifier	Bogen
1	717	Microphone	Electrovoice
2	PA30R	Paging Speaker	Electrovoice
1	MS3181-14C	Dust Cap	M[illegible]

7.8 Data System Components

The data system components used with the VP METRRA System are listed below.

Quantity	Part Number	Description	Manufacturer
1	Special	Interface Unit	MDB Systems
1	Nova 1200	CPU	Data General
1	Model 1145	Tape Transport	Wangco
1	ASR 33	Teletype Unit	Teletype
1	RAF3075BA	Reader/Punch	Remex

8. MISCELLANEOUS DATA

8.1 Instructions Furnished with Generator by Manufacturer

1. IM-88 "Installation and Operation Brushless Alternator Systems Using CS-350 Regulator" (Kurz and Root Company, Appleton, Wisconsin).

2. Part No. 205075-C "Operations and Maintenance Manual - Three, Four, and Six Cylinder Overhead Valve Diesel Engines" (White Engines Inc., Hercules Engine Division, 101 11th Street, S.E., Canton, Ohio 44702).

3. Part No. 40-0090008-A "Parts List Prepared for Generator Set Power Units - Gasoline and Diesel" (White Engines Inc.).

4 C-32099 "Schematic/Wiring Diagram D.C. Controls" (Kurz and Root Company).

5. C-35390 "Dimensional Outline w/Base and Housing-KD-20 w/Roof Mounted Silencer" (Kurz and Root Company).

6. B-35389 "Wiring Diagram Engine Controls (Manual Start) Diesel Eng. w/Alt." (Kurz and Root Company)

7. "Wiring Diagram, AC Controls (C-33912)" (Kurz and Root Company).

8.2 Sources of Maintenance Information for VP METRRA System

It is anticipated that, during the life of the system, specialized information may be required to keep the system operational. Sources of such information are presented below for reference.

8.2.1 Overall System

Contact Marvin J. Frazier or Reymond F. Elsner at IIT

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Research Institute, 10 West 35th Street, Chicago, Illinois 60616. Telephone 312/225-9630.

8.2.2 Transmitter

The transmitter was designed and constructed by Acrodyne Industries, Inc., 21 Commerce Drive, Montgomeryville, Pennsylvania 18936. Telephone 215/368-2600. Mr. George Roshon is cognizant of the overall transmitter and was Program Manager.

8.2.2.1 Vacuum-Tube Cavities

Specific inquiries about the 10 watt, 100 watt, 1 kilowatt and 5 kilowatt cavities should be referred to Mr. Joe De Courcelle at Acrodyne who was Project Engineer on these units. Problems with the special Teflon coupling capacitors should be referred to Mr. De Courcelle or Mr. John Zemany.

8.2.2.2 Solid-State Pre-Amplifiers

These amplifiers provide drive to the 10 watt cavity. Contact Mr. Willy Rose, who was the Project Engineer on these units at Acrodyne.

8.2.2.3 Mechanical Items

For mechanical items, cont act Mr. John Zemany, who was in charge of the mechanical system design, at Acrodyne.

8.2.2.4 Special Type 8942 Vacuum Tubes

Due to the grid-resonance problem (See Section 9 - Difficulties, Conclusions and Recommendations), selected replacement Type 8942 tubes should be ordered from Eimac Division of Varian Associates. Specify that tubes are to be specially selected by Mr. Wendel Hardman of Eimac's Salt Lake City, Utah, Plant to minimize the grid resonance problem.

8.2.3 Crystal-Controlled Frequency Sources

These items were custom-made by Spectra Electronics, 330 Mathew Street, Santa Clara, California 95050. Telephone 408/249-2470. Contact Mr. Dave Mattush or Mr. Sam Mashburn.

8.2.4 Receiver

The receiver was designed and developed by the Astro Communications Laboratory, 9125 Gaither Road, Gaithersburg, Maryland 20760. Telephone 301/948-5210. Mr. Carl Whitenton was the designer and should be contacted regarding receiver problems.

8.2.5 Antennas

Four of the system's six antennas were developed specifically for the system by the Antenna Corporation of America, 314 Ruth Road, Harleysville, Pennsylvania 19438. Telephone 215/256-9511. Contact Mr. Joe Bohar about both technical and nontechnical matters.

8.2.6 Truck Body

The specially-built truck body was fabricated by the Erlinder Manufacturing Company, 12221 South Indiana Avenue, Chicago, Illinois 60628. Telephone 312/264-5300. Mr. Al Kulig is the person to contact regarding any details of the truck body.

8.2.7 Air Conditioning System

The air conditioning system was selected and installed by the Crown Temperature Engineers, Inc., 4555 North Elston Avenue, Chicago, Illinois 60630. Telephone 312/777-6737. Mr. Ned Levine was the system engineer.

8.3 <u>Electrical Specifications for Crystal-Controlled Frequency Sources</u>

8.3.1 <u>RF Output Frequencies</u>

A total of five (5) crystal-controlled oscillator units are required, one of each of the following frequencies:

230 MHz ± 2 MHz
307 MHz ± 2 MHz
436.1 MHz ± 2 MHz
550.9 MHz ± 2 MHz
737.0 MHz ± 2 MHz

Each oscillator will have two RF output ports, one at the above frequency and the other at its third harmonic.

8.3.2 <u>RF Output Characteristics</u>

8.3.2.1 <u>Fundamental Frequencies</u> (Listed in 8.3.1)

The power output should be adjustable between 200 and 400 milliwatts for a 50 ohm load.

Amplitude modulation on the output should be down by 60 dB or greater.

Third harmonic rejection should be greater than at least 50 dB.

These waveform specifications, including frequency stability requirements listed in Section 8.3.4 must be maintained under a condition of varying VSWR at the oscillator output port. Maximum allowable VSWR variations will be mutually agreed to at a later date.

8.3.3 Third Harmonic Output

Power output of one milliwatt into a 50 ohm load is required.

The third harmonic at this output port should be down at least 50 dB.

AM modulation at this port must be down at least 60 dB.

Pulse amplitude modulation due to a varying load at the fundamental RF output port should not be noticeable at this output port.

8.3.4 Oscillator Stability

8.3.4.1 Short Term

The width of the output frequency spectral line at the 3 dB points should be guaranteed to be one Hertz or less for the three lower frequency oscillators, i.e., at 230, 307, and 436.1 MHz. Corresponding widths at 550.9 and 737.0 MHz are 1.2 and 1.5 Hz, respectively. These latter widths shall be verified by direct measurement.

The oscillator noise sideband power in a 1 Hz bandwidth will be down from the carrier by at least:

30 dB at 10 Hz separation from carrier
50 dB at 100 Hz separation from carrier
70 dB at 1 kHz separation from carrier
90 dB at 10 kHz separation from carrier
110 dB at 100 kHz separation from carrier

8.3.4.2 Long Term Stability

Stability should be equal to or better than one part in a million for an ambient temperature range

of 25°C to 35°C. The crystal shall be temperature stabilized in an oven to 0.1°C or better over this range.

At constant temperature, the oscillators should be stable to better than one part in ten million over a 24 hour period.

8.3.5 Environmental Effects

Spectra Electronics Inc. will provide consultation to IIT Research Institute which will allow evaluation of the maintainability of the frequency stability required in Sections 8.3.4.1 and 8.3.4.2, under field conditions of varying temperature and vibrational environments. Existing deficiencies will be corrected upon mutual agreement of conditions.

Oscillator susceptibility to microphonics and vibration shall be less than one part in 10^9/g.

8.3.6 Crystal Oscillator for Receiver

An additional crystal oscillator is required with the following specifications:

Output frequency to be exactly three times plus 160 MHz of the highest frequency oscillator specified in Section 8.3.1.1. This frequency is approximately 3 x 737.0 + 160.0 = 2371 MHz.

Output power level of + 15 dBm into 50 Ω.
Unit to operate from +24 volts supply.
Dimensions approximately 2-3/4" x 2-1/4" x 2".
Electrical characteristics shall be commensurate with those of the oscillators specified in Section 8.3.1 Namely, the following sections shall be applicable: 8.3.2, 8.3.4.1, except for center line width of five cycles or less, 8.3.4.2, and 8.3.5.

RF output connector shall be SMA type. Power connector will be specified at a later date.

8.4 Attenuation Curves for Coaxial Cables Used in the System

Figure 71 is a plot of attenuation versus frequency for coaxial cables used in the VP METRRA System, both internally and externally.

8.5 Schematic Diagrams for Pre-Amplifier Box and Attenuator Control Box

The pre-amplifier box schematic diagram is shown in Fig. 72, while that for the attenuator control box is shown as Fig. 73.

8.6 Exterior Cabling

A block diagram of the exterior cabling is shown in Fig. 74.

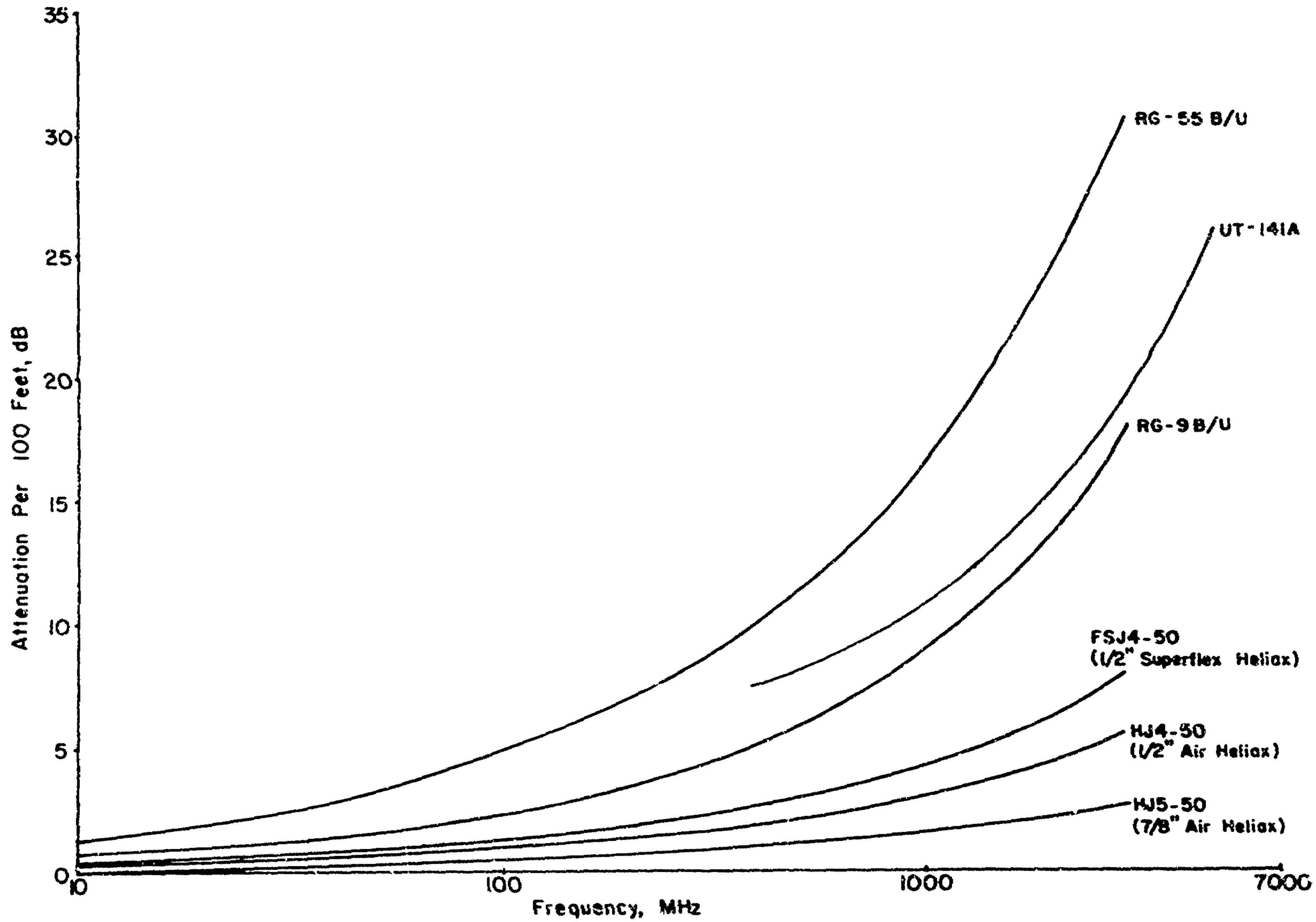


Fig. 71 ATTENUATION OF METRRA COAXIAL CABLE

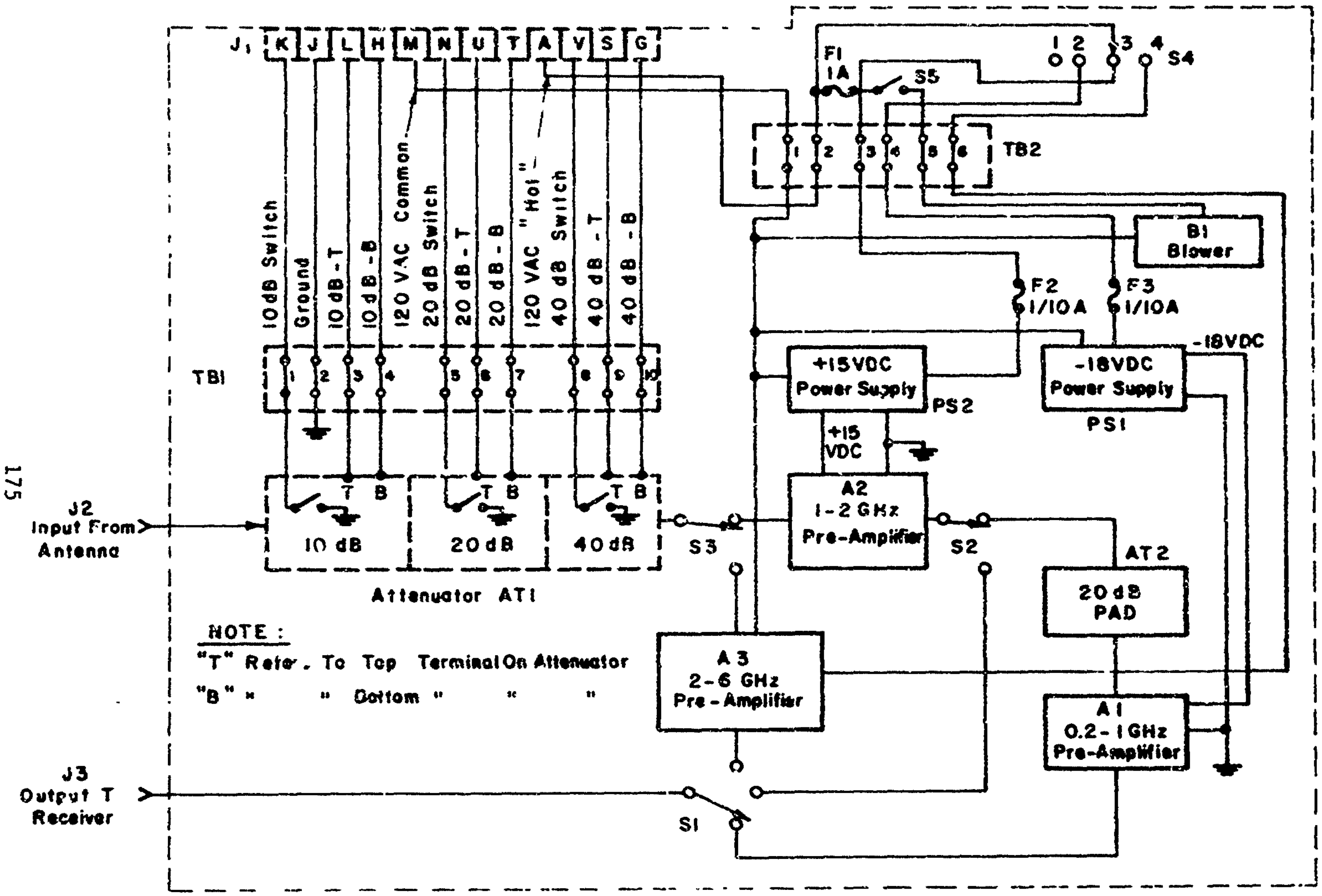
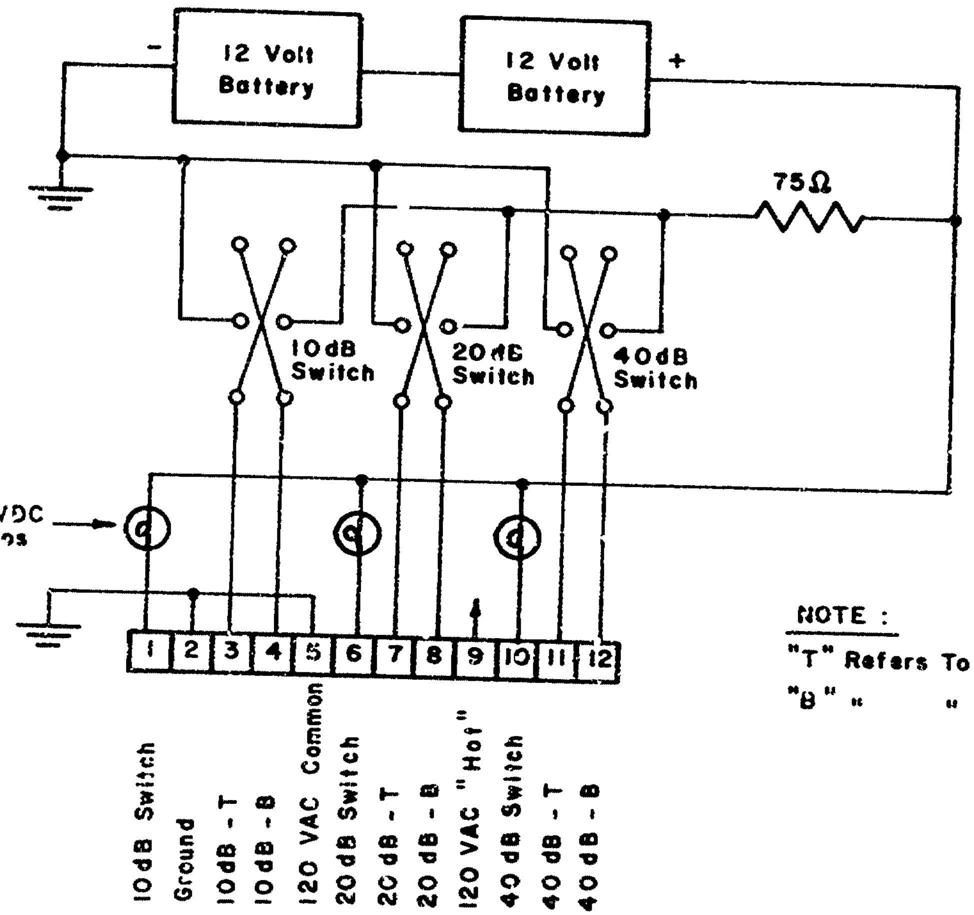


Fig. 72 SCHEMATIC DIAGRAM OF PRE-AMPLIFIER BOX



NOTE :

"T" Refers To Top Terminal On Attenuator

"B" " " Bottom " " "

Fig. 73 SCHEMATIC DIAGRAM OF ATTENUATOR CONTROL BOX

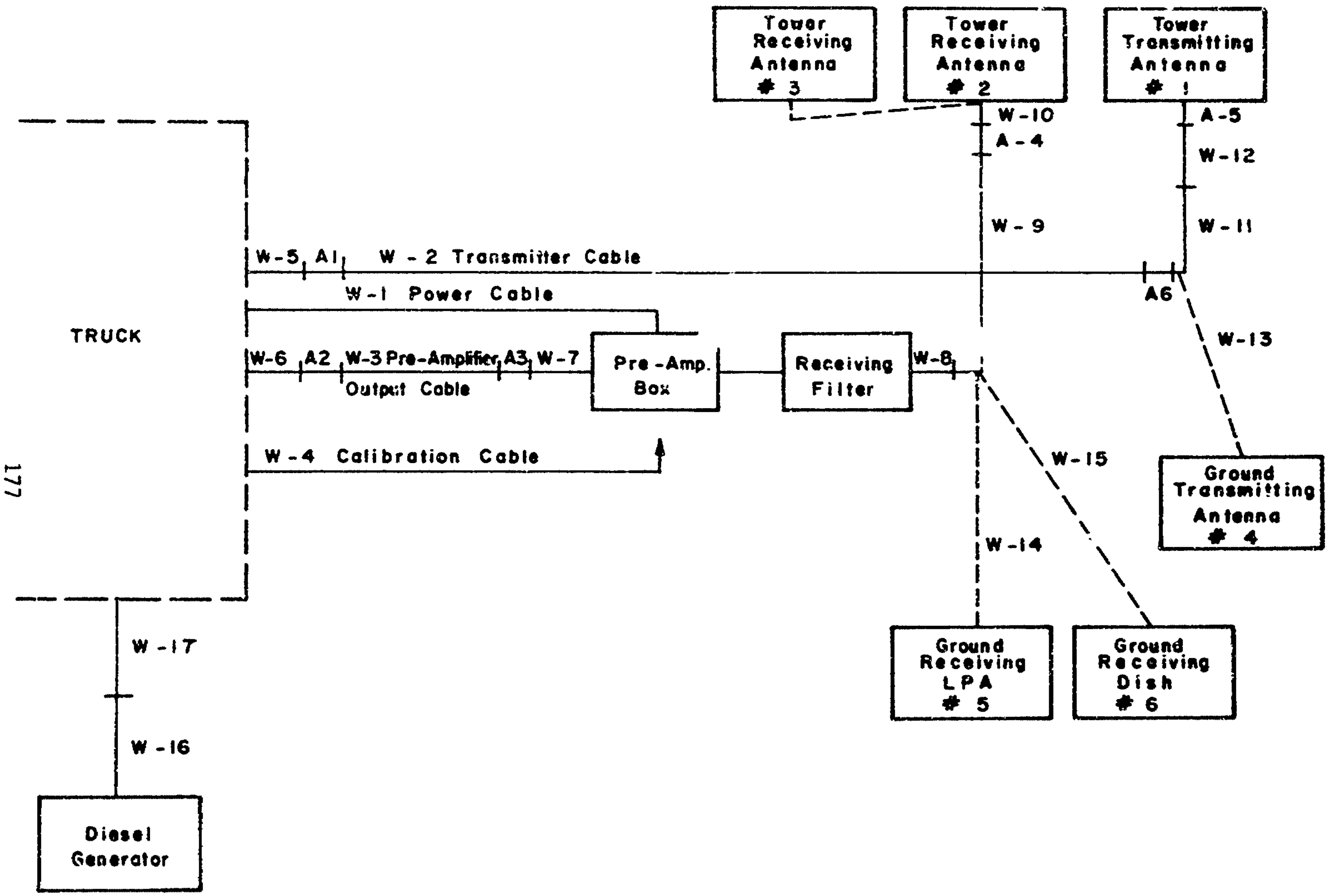


Fig. 74 EXTERIOR CABLING

9. CRITICAL EVALUATION OF SYSTEM

The VP METRRA System is capable of operating for sustained periods under various weather conditions. As a measurement system, it has sufficient pulse power to insure returns from the majority of targets tested; however, more power would be desirable when testing small targets. If CW testing were required, only about 20 to 35 watts of power would be obtainable due to high-voltage power supply substitutions to reduce residual 60 Hz-related noise from the transmitter output. If needed, these power supplies could be paralleled with same-type units to obtain increased CW power.

The transmitter has reliability problems; however, this must be "lived with".

Overall receiving system noise figure is about 6 dB. New pre-amplifiers would reduce this only slightly.

The antennas are not linear and were very nonlinear until reworked by IITRI.

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10. SYSTEM SHORTCOMINGS AND POSSIBLE CORRECTIONS

10.1 System

10.1.1 Diesel Generators

Use of external diesel generators to power the VP METRRA System proved acceptable but not fully satisfactory because of occasional sudden shut-downs. Normally, after turning the transmitter off, an internal timing delay keeps the blowers running for an additional three-minutes after turn-off to cool the vacuum tubes. When the diesel generators suddenly stop, the blowers also stop, thus reducing tube life. The tube manufacturer stated that the tubes could not stand shut-downs without the additional cooling. Periodically, testing time was lost due to need for tube replacement. It is considered that some decrease in tube life is relatable to the sudden loss of AC power.

One possible correction for this situation is to use an inverter, switched into operation by failure of the diesel generator, which would provide AC power to the blowers for a three-minute period. A better solution would be to employ a commercial power line; however, this approach could not be implemented at Aberdeen Proving Ground due to excessive time and cost.

The system can operate from standard military generators without modifying the generators. Problems with inadvertent shut-downs are the fault of the generators and not the VP METRRA System.

10.1.2 System Warmup

To insure adequate phase stability, it was found that the receiver requires about a two-hour warm-up and the transmitter about one hour. Stability of the crystal controlled sources increases with aging.

Since four of the five receiver frequencies are not crystal-controlled, warmup time could be reduced by making them crystal-controlled.

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Obtaining the degree of system temperature stability required by System coherency requirements proved a difficult problem. The ideal air-conditioning system to be used with such tight coherency specifications should operate continuously (rather than being cycled on and off) as does the existing system, and provide a constant but adjustable internal temperature. Its cooling capacity should be matched to the METRRA vehicle's or housing's heat generation. The major temperature problem with the VP METRRA System developed primarily because the transmitter was operated with heat output less than the original design anticipated. A part of this reduced heat load is attributable to employing only one transmitter in pulse mode for harmonic tests as opposed to the original design concept of using two CW transmitters for intermodulation tests (worst case for heat generation). With a reduced internal heat load, the air-conditioning system provided too low a van temperature for system stability. Since the volume of air supplied by the air conditioner could not be restricted without damage to the unit, the van temperature could not be stabilized at nominal temperatures (70°-80°F) until the 5 kW heater located in the air-conditioning ducting was replaced by a 10 kW unit.

Below 70°F, the system was found to have excessive phase instability. Phase stability is defined as the stability of a received third-harmonic signal as compared to the transmitter-derived reference signal.

The system was found to be insensitive to power line frequency variations, but was extremely sensitive to line voltage variations. It is thought that some of the voltage variation sensitivities, measured in terms of system phase stability, are indirectly related to temperature sensitivity. The system voltage sensitivity disappeared after

installation of highly-regulated heater (filament) supplies on the transmitting vacuum tubes (highly-regulated high voltage supplies were installed previous to this to reduce 60 Hz related components in the transmitter output). It is recommended that, for similar applications, the system designer specify tight-tolerance temperature coefficients on regulated heater power supplies. A few millivolts variation on the tube heater voltages for the system caused intolerable instability. If the regulated heater supplies do not have a tight temperature coefficient but are otherwise tightly-regulated, heater voltages can change with temperature. For the existing system, a temperature coefficient of 0.01% per degree centigrade was found adequate.

It is considered impractical to attempt to provide adequate system stability below 70°F for the existing system; it is practical to operate in the 70°-80°F range where such stability is obtainable.

10.2 Transmitter

The transmitter has several shortcomings: marginal power output at the two highest frequencies, difficulty in changing vacuum tubes, need for specially-selected output tubes (5 kW stage), and poor reliability of the special cavity tuning capacitors.

10.2.1 Marginal Power Output

The transmitter has a large power reserve at 230.0 MHz and almost zero reserve at 737.0 MHz. Gradual degradation results in inability to obtain the required power output at the two highest frequencies except when the tubes are reasonably new.

This is a design problem and re-design is impractical for the existing system.

10.2.2 Changing Vacuum Tubes

To change a vacuum tube, the cavity must first be removed from the transmitter after disengaging shafts, gears, cables, air hoses, etc. This is a complicated and time-consuming procedure. After removal, the cavity must be placed on a flat surface and partially dismantled to permit access to the tube. After replacing the tube, the process has to be reversed. Shaft alignment is time-consuming.

This also is a design problem and re-design is impractical for the existing system; however, it is suggested that possible future transmitters employ improved mechanical design to permit quick tube changes. One possible approach is to employ a small removable cover over the vacuum tube section.

10.2.3 Specially-Selected Tubes

An unusual problem developed with the Eimac Type 8942 vacuum tubes used for the 5 kW transmitter stages. It was found that these tubes are sensitive to certain PRF's. A grid electro-mechanical resonance is set up when a PRF of approximately eight kilohertz is employed. Physical movement of the grid can cause a grid-to-cathode short. The existing system solved this problem by setting up operational procedures so that a PRF of 8 kHz is never used. In addition, special 8942 tubes selected by the manufacturer for minimum mechanical grid resonances have been employed. Since the 8942 is considered as one of the best tubes for the present application, designers of future systems should consider the grid-resonance problem.

Recent correspondence with the tube manufacturer has indicated that this system has received the last two specially-selected tubes in stock and that 60 to 90 days should be allowed for new procurement.

The impact of this should be considered for future design.

10.2.4 Special Cavity Tuning Capacitors

The transmitter employs specially-fabricated coupling capacitors in all vacuum tube stages. All have been acceptable except those used as the 5 kW plate coupling capacitors. These high-power units appear to have a service life of between three and six months, thus necessitating frequent replacements. It appears that this problem could be alleviated with redesign and extensive testing but this is not a practical solution for a field-test operation.

10.3 Receiver

There have been no outstanding difficulties with the receiver except for occasional replacement of semi-conductors; however, the phase shifter associated with the receiver input does not have sufficient range for all operating conditions without use of additional short lengths of coaxial cable. A single-knob phase shifter with wider range would be desirable.

10.4 Antenna Systems

10.4.1 Antennas

Many difficulties were encountered with nonlinearities in the system antennas. The main problem occurred with the "ground" transmitting log periodic and both receiving log periodics. All three antennas were specially designed for the VP METRRA System and used metal longitudinal rods

as stiffeners. Metal screws held the four sides to these four rods, resulting in nonlinearities. A temporary remedy consisted of taking the metal rods and using nylon screws to fasten the antenna sides to them. Eventually, the metal rods were removed and strong glass-fiber tape was used to assemble the four sides after nonlinearities reappeared.

It is recommended that future antennas do not use metal-to-metal bolted, rivetted, or similar fabrication techniques. Use welded, soldered, brazed or similar fastenings for metal-to-metal joinings. However, it is suggested that insulated fastenings be used instead of metal-to-metal ones. Larger cross-sections might be judiciously employed in nonmetallic structural members. When nonmetallic screws are employed, an increase in diameter and number of screws might be required to obtain mechanical strength equivalent to using metallic fastenings.

10.4.2 Antenna Polarization (Tower)

The tower antenna polarizations are changed manually. This is very inconvenient and somewhat time-consuming, especially in inclement weather. There does not appear to be any practical alternate method of changing polarizations.

10.4.3 Transmission Lines

It is suspected that movement of the antenna system transmission lines is the cause for many cases of transmission line nonlinearity. This could be alleviated to a great extent by using coaxial switching and fastening cables to prevent movement from wind, etc.

10.4.4 Filtering

The present degree of filtering in the transmitter output and receiver input lines is deemed sufficient for

normal operation; however, another 20 dB would preclude most system residual third-harmonic signals due to minor variations in transmitter tuning. The major difficulty is that filter manufacturers can not measure responses down by more than about 80-90 dB.

The tubular transmitting low-pass filters were found to be extremely sensitive to temperature changes, which caused very large phase instabilities. When these filters were exposed within the van (at the transmitter) and the van door was momentarily opened, excessive phase instability resulted. This was cured by mounting the selected filter near the transmitter front panel so that the closed transmitter door prevents stray air currents from affecting it. It is suggested that future systems use this technique or, as an alternate, enclose the filter in a styrofoam or similar thermal enclosure.

10.4.5 Manual Switching

Manually switching coaxial cables at the pre-amplifier box and at the antennas involves a loss in time and also increases the possibility of creating nonlinear junctions due to cable and connector movement. Remote controlled coaxial switching could obviate these problems; however, the coaxial switches selected must not themselves be nonlinear.

Manually-operated switches on the pre-amplifier box could also be operated remotely.

10.5 Data System

During the early part of the data-taking phase, it was found that the magnetic tape transport's head assembly plate was severely misaligned so that some tapes were unreadable

by MERDC. Previous tapes submitted to MERDC were judged to be perfect. It has proven impossible to determine when the misalignment occurred or how it occurred. Inspection by a factory-authorized service representative proved inconclusive. Repeated telephone conversations with the factory's Service Manager brought the comment that, in all his experience, he had never heard of a transport having such an inordinate amount of misalignment nor could he account for how it might have occurred.

The head assembly plate was re-aligned by IITRI using a Master Skew Tape and supplementary shimming well in excess of that considered normal by the manufacturer, using telephone conversations with the Service Manager as guides. After adjustment, test tapes were delivered to MERDC and were found to be acceptable.

Periodic re-checks of head alignment has shown no changes.

It is possible that examination by factory personnel might provide more information as to the cause of the misalignment.

11. CONCLUSION

This Final Report/Instruction Manual has described the Variable Parameter METRRA System and provided details of operating procedures, performance, maintenance, etc., as well as suggestions for remedying existing shortcomings.

APPENDIX A

DATA SYSTEM DETAILS

1. INTRODUCTION

The Data System was designed to work with the transmitting and receiving instrumentation. Data taken using both large and small targets was processed and recorded on magnetic tape.

Following sections describe the details of the Data System, shown in simplified form in Fig. A-1. The nucleus of the system is the Central Processing Unit (CPU) working in conjunction with the Interface Unit. Peripheral equipment includes the Tape Transport, Reader/Punch and the Teletype Unit.

2. TAPE FORMAT

The data is recorded on magnetic tape at 800 bytes/inch with 6 bits plus odd parity per byte. The format of the recorded data is illustrated in Figures A-2, A-3, and A-4. As seen from these figures all the data records consist of 4100 bytes of data plus 40 bytes of trailer information. The 4140 byte records are separated by inter-record gaps. Files records are placed between experiments. In the case of the large target experiment, 512 or 513 records are included between file records. The trailer data, with the exception of the record number (byte numbers 4101 and 4102), are identical. The record number increases from 1 to 512 over the 512 records of the experiment. A record number of 0 indicates that a free text record is included in the experiment.

In the case of small target experiments, all the data of a given small target is included between file records. However, in this case, the record numbers increase from 1 to 50 for a given run number. The number of runs (50 record groups) included in a small target experiment is determined by the personnel conducting the experiment.

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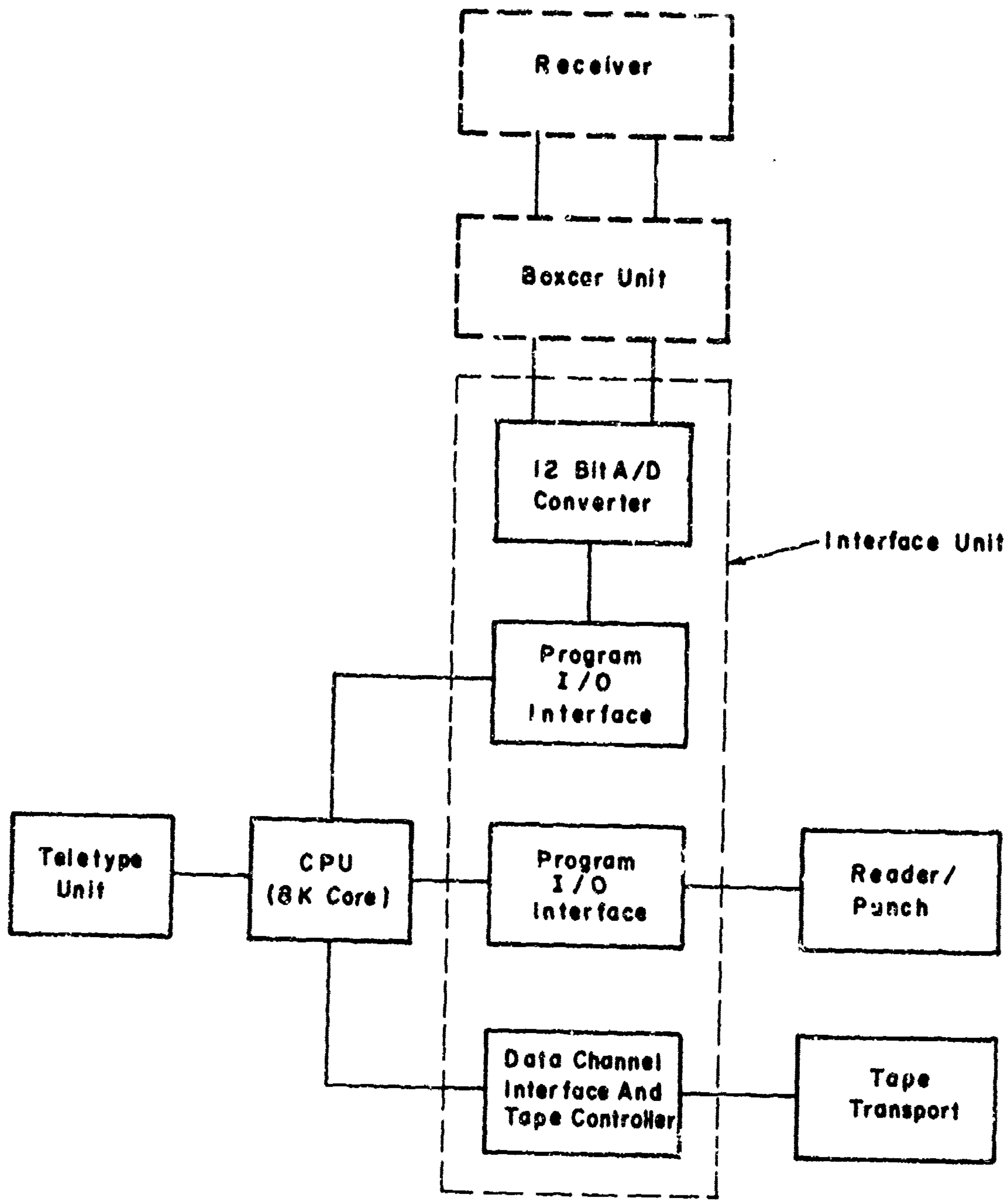
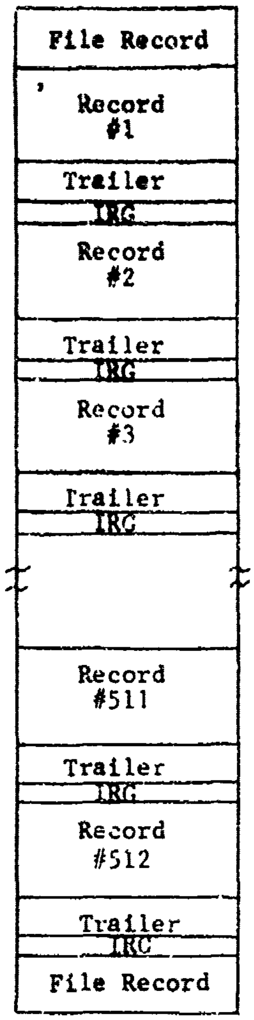
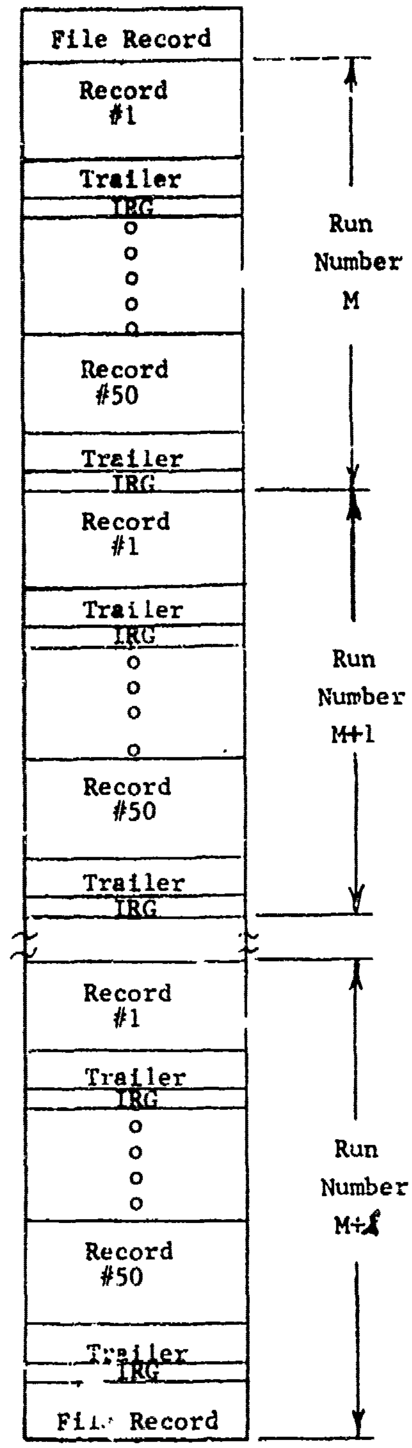


Fig. A-1 SIMPLIFIED BLOCK DIAGRAM OF DATA SYSTEM



LARGE TARGET EXPERIMENT

FORMAT - ALL RECORD TRAILERS BETWEEN FILE RECORDS HAVE SAME RUN NUMBER



SMALL TARGET EXPERIMENT FORMAT

Fig. A-2 TAPE FORMAT

RECORD BYTE NUMBER	A/D BIT NO.	A/P SAMPLE NUMBER	RECEIVER OUTPUT
1	11 10 9 8 7 6	1	IN-PHASE
2	5 4 3 2 1 0		
3	11 10 9 8 7 6	2	QUADRATURE
4	5 4 3 2 1 0		
5	11 10 9 8 7 6	4*	IN-PHASE
6	5 4 3 2 1 0		
7	11 10 9 8 7 6	5	QUADRATURE
8	5 4 3 2 1 0		
…	…	…	…
4097	11 10 9 8 7 6	3074	IN-PHASE
4098	5 4 3 2 1 0		
4099	11 10 9 8 7 6	3075	QUADRATURE
4100	5 4 3 2 1 0		
4101	TRAILER DATA		

*Every third sample monitors transmitter power and is not recorded on tape.

FIGURE A-3. DATA RECORD FORMAT

RECORD BYTE NO.	BYTE I.D.	BYTE FORMAT
4101 2	RECORD NO.	BINARY
3 4 5	RUN NO.	6 BIT ASC II
6	TARGET CONDITION	
7 8 9 10	POWER DENSITY	
11 12 13 14 15	TARGET ORIENTATION	
16 17 18 19 20 21 22 23	TARGET DESIGNATION	
24 25 26 27	RECEIVER CALIBRATION	
28 29 30 31	TRANSMITTER FREQUENCY	
32 33 34 35	TRANSMITTER MODULATION	
36	TRANSMITTER POLARIZATION	
37 38 39	DATE	
40	EXTERNAL EXCITATION	

FIGURE A-4. DATA TRAILER FORMAT

As in the large target experiment, record numbers of 0 indicate free text records. The final records written on tape consist of four end-of-file (EF) records.

3. DATA FORMAT AND STORAGE

In order to facilitate handling by the 15 kHz sample rate of the three input channels, the A/D converter output was wired in a format compatible to use in writing tape. Here, the sign bit of the A/D converter, bit #1, lies in bit position 2 of the computer. As seen in Figure A-5, the six most significant data bits lie in CPU bit positions 2-7, while the six least significant bits lie in bit positions 10-15 of the CPU. Thus the 3777_8 output of the A/D converter with +10V input appears as 17477_8 in the CPU while the 4000_8 output part of the A/D converter for -10V appears as 20000_8. Conversion of the stored octal number to a decimal value thus involves first, conversion in binary; second, shifting the bit positions 2-7 two positions right to bit positions 3-9; and third, converting the resulting octal number to decimal. The output voltage V_o is computed by

$$V_o = \frac{N_{10}}{2047} \times 10.$$

4. DATA SUMMARY

In order to insure that the data recorded lies within the linear range of the data acquisition system, a real time summary of the sampled data from both receiver channels as well as the power output channel is performed. An example of this data

A/D BIT NUMBER →				1	2	3	4	5	6			7	8	9	10	11	12	
CPU BIT NUMBER →		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
+10 v	BINARY	0	0	0	1	1	1	1	1	0	0	1	1	1	1	1	1	DATA/SAT TEST
	OCTAL			1			7			4			7			7		
307.7 mv	BINARY	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	NOISE TEST
	OCTAL	0		0			0			0			7			7		
4.88 mv	BINARY	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	
	OCTAL	0		0			0			0			0			1		
0 v	BINARY	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	OCTAL	0		0			0			0			0			0		
-4.88 mv	BINARY	0	0	1	1	1	1	1	1	0	0	1	1	1	1	1	1	
	OCTAL			3			7			4			7			7		
-307.7 mv	BINARY	0	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	
	OCTAL			3			7			4			0			0		
-10 v	BINARY	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	DATA/SAT TEST
	OCTAL	0		2			0			0			0			0		

Figure A-5 DATA STORAGE FORMAT

summary is seen in Figure A-6 below. The detected power output voltage is sampled and the maximum and minimum values of this parameter typed out. In addition to these output messages, a parity error count output is typed if the number of records containing parity errors exceeds zero. An "Output Saturated --- Repeat Experiment" message is provided if samples fall in the 10V bin of the receiver output.

In addition to the data summary provided during the recording, two test modes are provided to set up the receiver gain prior to recording the data on tape. A saturation test mode duplicates the above output only during a period of 50 records.

5. COMPUTER SOFTWARE

5.1 Memory Allocation

As seen in Figure A-7, Computer Memory Allocation, at most five programs lie in the computer memory at one time. The maintenance routines load starting a location 274. The magnetic tape routine normally lies in this location as it is included in the system tape. The other test routines require loading before they can be used. The second program in the machine is DEBUG. This is a standard Data General program which allows examining locations in memory as well as performing other functions on other programs as described in document 093-000020-00 in DEBUG Users Manual. A command summary sheet is included in with the plastic covered command summary (Table A-2). The third program in the machine which occupies most of memory is the MERDC real time operating system. A discussion of this program as well as the program listing is included in this Appendix. The fourth program is the binary block loader which lies within the data buffer of the MERDC program. This program

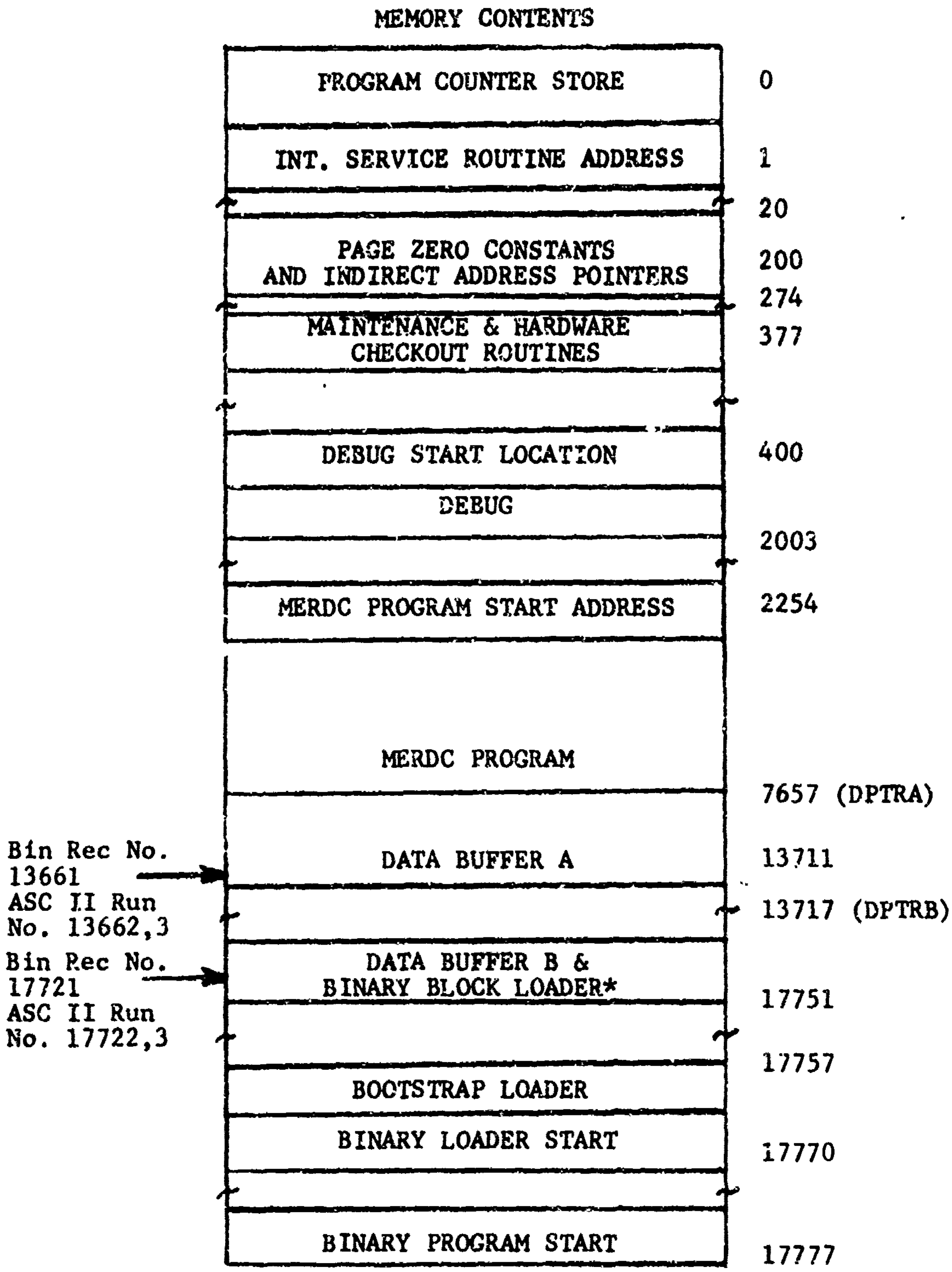
ST

PWR. RANGE PMAX = 19.983V, PMIN = .000V

INPHASE OUTPUT VOLTAGE RANGE
MAX (+) = 08.183V MAX (-) = 08.208V
AVERAGE ABSOLUTE VALUE = .000V

QUADRATURE OUTPUT VOLTAGE RANGE
MAX (+) = 08.183V MAX(-) = 08.208V
AVERAGE ABSOLUTE VALUE = .000V

FIGURE A-6. DATA SUMMARY



*NOTE: Data Buffer B overwrites the Binary Block Loader.

FIGURE A-7. COMPUTER MEMORY ALLOCATION

must be re-loaded before any binary programs can be loaded into the machine. The fifth program in the machine is the bootstrap loader. The listing of this program is included on the Nova Instruction Reference Card which is included with the command summary.

5.2 MERDC System Software

A block diagram of the MERDC program is seen in Figure A-8. The program must be started at EXRCS. The location of this program is seen in the memory map of the program listing. The EXRCS program initializes the operating system. The next program entered is the EXEC. This program decodes the input commands, entered through the teletype, and transfers the control to a number of operating programs. The WEOF program, entered by command "EF↓" writes an end-of-file record and returns the program control to the EXEC as do all of the programs on the right side of the block diagram. The FRTXT program allows the capability of entering a record of up to 5000 characters of text. Editing commands are included to delete the last character, the last line, and the entire text. In addition, commands are available to list the last line as well as the text. These commands are tabulated in the command summary table. The ITRLR program provides the capability to input 40 ASC II six bit characters which form the trailer. The format in which the trailer characters are entered is seen below.

IT

Run Number (3D) = ΦΦΦ
Target Cond.(Q,A,O) (IL) = Φ
Pwr. Denstity (4D) = ΦΦΦΦ
Target Orient. (3D 2D) = ΦΦΦΦΦ
Target Desig. (8D) = ΦΦΦΦΦΦΦΦ
Recvr. Calib. (4D) = ΦΦΦΦ
Frequency (MHz)(4D) = ΦΦΦΦ
Modulation (4D) = ΦΦΦΦ

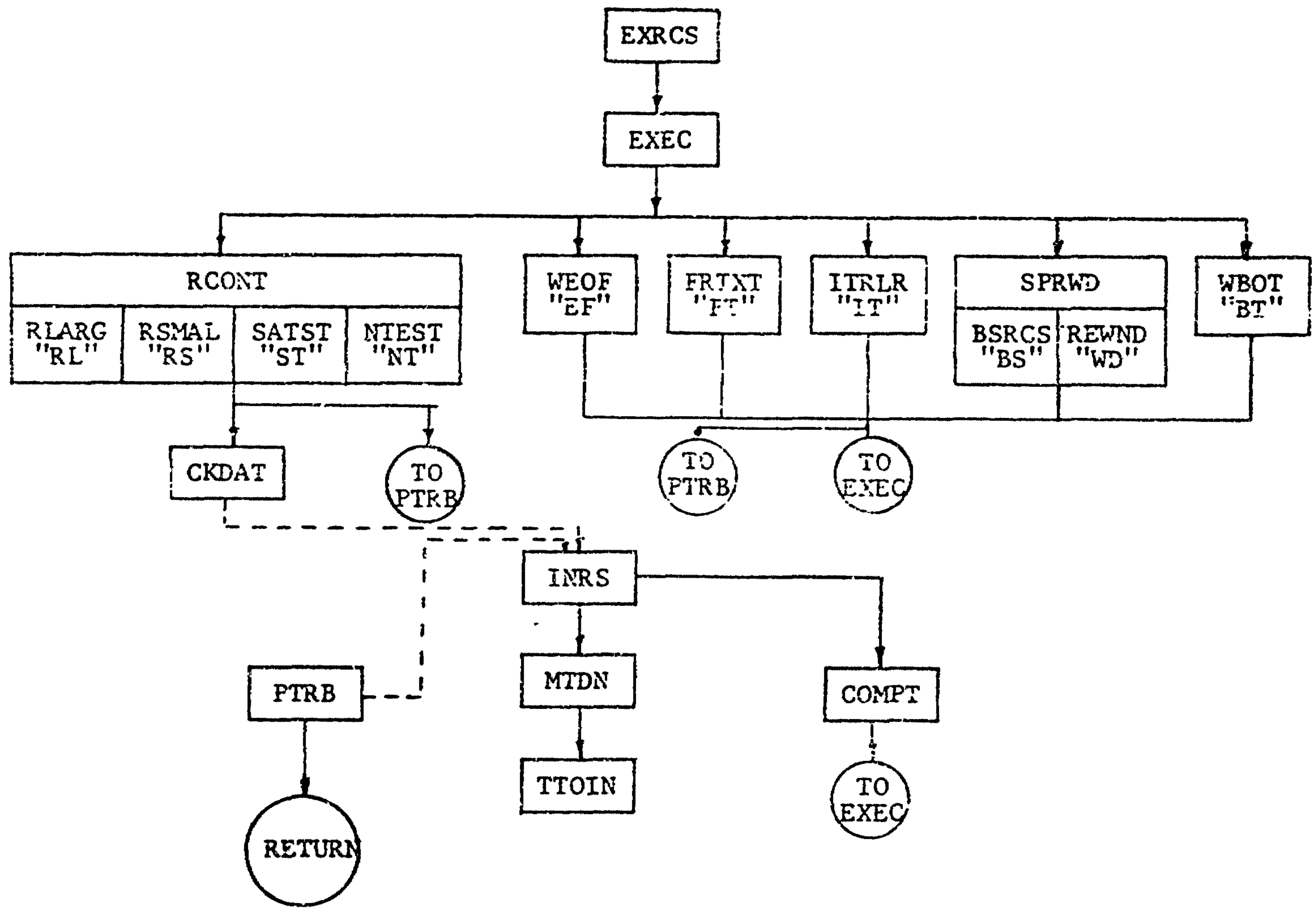


Figure A-8. MERDC PRCGRAM ORGANIZATION

Polarization (H,V) (IL) = Φ
Date (3D) = ΦΦΦ
Ext. Excitation (IL) = Φ

The record number, which is the first two characters of the trailer, is not seen in the above format but is entered automatically during the data run. The input commands required to change or list the trailer information are included in the command summary table. The SPRWD program enables the tape drive to backspace over the records written in case of errors in the data via input command BS↓. The tape drive is also rewound through this program via the input command WD↓. The WBOT program erases five inches of tape from the reflective BOT marker.

The above group of programs provides means of formatting the tape and inputting information on the experiment parameters. The RCONT program in the left portion of Figure A-8 sets up the program constants to run the A/D converter and the tape drive, and to summarize the sampled receiver outputs. The SATST and NTEST entry points into the program run the A/D converter for a duration of 50 records although no tape is written. The RLARG and RSMAL entry points set the A/D converter and magnetic tape drive to write 512 and 50 records respectively. The exit point of the RCONT program passes the program control to the CKDAT program. The CKDAT program sums the absolute values of the A/D output for the two receiver output channels and flags overvoltage samples. The CKDAT program is interrupted when the A/D converter has completed digitizing a sample or the tape drive has finished writing a record. At this time, control is passed to the INRS program which stores the sampled value or the MIDN program checks the status of the tape drive after each record is written.

After the required number of data samples have been taken, the INRS program passes control to the COMPT program. Here the absolute value sums formed in the CKDAT program are used to compute and output the data summary of the max, min, and average absolute channel values as well as the number of parity error records and the power output max and min values.

The two remaining programs in the block diagram of Figure A-8 are the TTOIN and PTRB. The TTOIN program contains the interrupt service routine for the teletype and, in conjunction with the PTRB program, handles the output of error messages and the output of the data summary from the COMPT program.

APPENDIX B
MEASUREMENT TECHNIQUES

1. LARGE TARGETS

1.1 General

Large targets were tested in accordance with Table I contractual requirements, which specified that all combinations of nine classes of targets, five examples of each type (four domestic plus one foreign), five frequencies, seven aspects, two antenna polarizations and three conditions (quiescent, activated and operating) were to be tested. Quiescent is defined as having the target's power turned off. Activated is defined as having the engine running but the target stationary. Operating is defined as having the target moving in a straight path normal to the bore-sight Poynting vector of the tower antennas. When operating, a vehicle's speed was set very slow so that in the course of the 104.96 second data run the vehicle remained within the designated target area.

Some types of targets such as fixed artillery were tested "quiescent" only since "activated" and "operating" modes did not apply.

The target area was located along a dirt road which passed 35 meters away from the antenna tower. The area was staked to aid in centering the targets and to delineate the limits for the "operating" tests.

Power density at the target was 0.87 watts per square meter.

1.2 Test Procedure

1. Select antenna polarization desired.
2. Tune transmitter to desired frequency and power level into the tower transmitting antenna (Paragraph 4.2).
3. Adjust the transmitting monitor (Section 4.4.3).
4. Tune receiver to desired frequency (Paragraph 4.3).
5. Adjust the boxcar unit's zero adjust (Paragraph 4.4.1) and range gate adjust (Paragraph 4.4.2).
6. The system is now adjusted but no target is present. If desired, a recording of this no-target state could be made and would indicate the level of residual third-harmonic in the overall system. This residual level is normally only a few millivolts, as indicated on the digital volt meter (DVM) which monitors the boxcar outputs. A higher level indicates system nonlinearity which should be remedied (see Appendix C).
7. Assuming that the residual third-harmonic is sufficiently low, have a suitable large target placed between the stake markers at an aspect of zero (target is to face essentially south).
8. For the quiescent test, insure that all active mechanical and electrical equipment such as engines, blowers and communications are turned off. The driver should exit from the vehicle and move out of the test area.
9. The IF gain control on the receiver should be adjusted until a reasonably strong signal is received from the target as shown on the DVM. The goal is to have as strong a signal as possible without saturation (ideally, just under

10 volts). Since most targets have wildly intermittent third-harmonic returns, operator judgment is required when setting the IF gain. If necessary, the remotely-controlled attenuator in the pre-amplifier box may have to be adjusted to increase or decrease the signal level entering the receiver.

10. The operator should begin the input trailer routine. At the appropriate place, K should be entered. K is found from the available charts, using the reading on the receiver's IF gain control dial.
11. At the end of the data run, examine the teletype print out. If either in-phase or quadrature channels saturated or if the absolute average value is deemed too low, repeat the experiment.
12. If the print out is acceptable, proceed to the next test by activating the target.
13. Repeat test procedure after possibly re-setting the IF gain control and re-zeroing the boxcar.
14. Have target turned 45 degrees clockwise and repeat the quiescent test.
15. Activate the target and repeat test.
16. Continue testing at 45 degree intervals until the 315 degree tests have been completed.
17. Perform the "operating" tests twice: once in each direction. Insure that the small log periodic receiving antenna is used while performing these tests; otherwise, the target will move out of the interaction area due to the narrow beamwidth of the dish antenna. A different K factor is used with this antenna.

18. Change antenna polarization and repeat the entire sequence.

1.3 Test Sequences

When testing a large number of targets, efficiency can be improved by judiciously optimizing the test sequences.

In general, the test sequence described in Section 1.2 for one frequency has been found to be optimum for one target. The entire sequence for one target's Table 1 requirements are listed in Table B-1.

Table B-1
TEST SEQUENCE FOR ONE LARGE TARGET

Transmitting Frequency (MHz)	Antenna Polarization	Test At:
230.0	Horizontal	7 Aspects, 3 Conditions
230.0	Vertical	7 Aspects, 3 Conditions
307.7	Horizontal	7 Aspects, 3 Conditions
307.7	Vertical	7 Aspects, 3 Conditions
436.1	Horizontal	7 Aspects, 3 Conditions
436.1	Vertical	7 Aspects, 3 Conditions
550.9	Horizontal	7 Aspects, 3 Conditions
550.9	Vertical	7 Aspects, 3 Conditions
737.0	Horizontal	7 Aspects, 3 Conditions
737.0	Vertical	7 Aspects, 3 Conditions

In practice, it has been found most efficient to test as many targets as are available without changing polarization or frequency. After completing testing of many targets at a given frequency and polarization, change polarization and repeat the tests. Change frequency only when no other tests can be performed without such a change.

2. SMALL TARGETS

2.1 General

Small targets were tested in accordance with Table I and Table II requirements, using the antenna installation shown in Fig. 11. Targets were mounted on rotatable wooden disks which could be mounted in two planes: with the plane of the disk essentially parallel to the earth (α = 0 degrees) or essentially perpendicular to the earth (α = 20 degrees).

2.2 Table I

Table I required that 28 targets (five samples of four classes plus eight samples of another class) be tested at all combinations of five frequencies and 14 aspects (seven with α = 0 and seven with α = 90 degrees). Power density was 20 watts per square meter at the target.

2.2.1 Test Procedure

1. Select α to be either 0 or 90 degrees.
2. Tune transmitter and receiver with no target.
3. Adjust the boxcar unit.
4. Check for residual nonlinearity.
5. Mount test target and set disk at zero degrees aspect.
6. Take data run, using "RL" instruction to provide 104.96 second data run length.
7. Set disk at 90 degrees aspect.
8. Repeat data run.
9. Set disk at 135 degrees aspect.
10. Repeat data run.
11. Repeat these tests until completion at 315 degrees aspect.

12. Change α to the other plane.
13. Repeat testing.

2.2.2 Test Sequences

Greatest efficiency is obtained when many targets are tested before changing frequency or α. After testing many targets at a given α, change to the other plane and repeat testing. Change frequency only when no other tests can be performed without such a change.

2.3 Table II

Table II required that 28 targets (five samples of four classes plus eight samples of another class) be tested at all combinations of four frequencies (230.0, 436.1, 550.9 and 737.0 MHz), four power levels (20,2, 0.2 and 0.02 watts per square meter at the targets), two best aspects (one with α equal to zero and the other with α equal to 90 degrees), two acoustic conditions (with and without acoustic excitation) and two target conditions (with and without targets).

Acoustic excitation required a sound pressure at the target of at least 100 dB referred to 0.0002 dynes per square centimeter, using a sine-wave frequency swept from 150 Hz to 2 kHz at a rate of two increasing sweeps per second. This was provided by a combination of function generator, an audio power amplifier and a horn-type outdoor speaker. The speaker was mounted on the second landing of the antenna tower. The function generator and power amplifier were installed in the shop van.

2.3.1 Test Procedure

1. Select α to be either 0 or 90 degrees.
2. Tune transmitter and receiver with no target.
3. Adjust the boxcar unit.
4. Check for residual nonlinearity.
5. Take data run with no target present.
6. Mount test target and rotate disk for maximum received signal.
7. Take data run at this aspect. Power density at target is to be 20 watts per square meter. Acoustic excitation is to be turned off.
8. Using the same aspect, reduce power density by 10 dB and take data run. Power is reduced by inserting a high-power 10 dB pad in the transmitter output line and adjusting the transmitter's controls slightly so as to obtain the desired output power as measured on the power meter located in the van.
9. Reduce power by another 10 dB by switching to the 20 dB pad instead of the 10 dB pad. Take data run.
10. Reduce power by another 10 dB by switching to the 30 dB pad instead of the 10 dB pad. Take data run.
11. Turn on the acoustic excitation and take data run.
12. Increase power density by 10 dB and take another data run.
13. Repeat with another 10 dB increase in power density.

14. Repeat once again with another 10 dB increase in power density.

15. Repeat entire sequence using the other α.

2.3.2 Test Sequences

Greatest efficiency is obtained when as many targets as possible are tested without changing α or frequency. Change frequency only when no other tests can be performed without such a change.

APPENDIX C

SYSTEM NONLINEARITIES

1. INTRODUCTION

In general, the most difficult operation when attempting to set-up the VP METRRA System for data-taking is to reduce abnormally high residual third-harmonic signals to manageable levels. This is difficult because tracing the sources of the residual is more art than science.

2. CAUSES OF RESIDUAL

High residual levels have been traced to improper choice of criteria when tuning the transmitter (normal filtering was insufficient when transmitter produced excess harmonics due to tuning criteria employed) and to nonlinear junctions in transmission line connectors and cables and nonlinearities in electrical or mechanical fastenings. In essence, a high residual level is caused by insufficient transmitter or receiver filtering or nonlinearities in the antenna systems.

3. LOCATING SOURCES OF RESIDUAL

The state-of-the-art limits the practical location of sources of residual to the brute force and replacement approaches, rather than to the measurement and analytical approaches, because of the time factor involved.

When excessive residual appears in the system, the first approach is to check the transmitting and receiving filter connections for tightness. Next, temporarily insert additional filters in these lines and notice whether the residual level has decreased. If it has decreased, transmitter tuning problems are indicated. If it has not decreased, then nonlinear junction problems are indicated.

When nonlinear junctions are suspected, the usual approach is to utilize a two-person team: one person actively searches for the nonlinearities while the other remains inside the van and monitors the residual level. The monitoring person uses the public address system to inform the searcher of changes in residual level that occur as the searcher checks items and substitutes components. This is a very difficult task for both people since communication between them is much slower than the usual rapidly-changing residual levels and correlations are hard to obtain due to the time lags. In some cases, the levels have independently dropped to zero or increased drastically without human intervention, thus increasing the difficulty in observing correlations.

In general, the searcher taps cables, antenna elements, etc. with an insulated rod and hopes for a correlation. Usually, this does not occur because, although most nonlinear junctions are extremely susceptible to mechanical motion, such physical motions are also transmitted elsewhere than the intended point. The best recourse then is to change coaxial jumper cables which connect the antennas to the Heliax transmission lines. For difficult cases, it is necessary to carefully examine (visually and by manually manipulating) the antennas, with power removed, for any looseness, corrosion or oxidation at joints and fastenings, etc. All antennas in close proximity should be inspected, even the one not being utilized at the moment. For extremely difficult cases, the antennas should be dismantled and rebuilt with care.

Nonlinear junctions have been found in many places. A consistent offender has been the tip of the ground LPA where

the internal coaxial transmission line's ends are soldered to the tips of the flat sheets forming the elements. These joints break with time, probably because of wind motion bending or twisting the antenna.

A similar problem has occurred to a lesser extent with the tower transmitting antenna. In both units, the input coaxial connectors have become loosely-mounted with time and thus nonlinear.

Coaxial cables have had broken pins. A more common cable problem is due to braid fastenings becoming loose at the cable connectors.

APPENDIX D

INFORMATION FORMAT FOR TRAILER

The trailer information which will be entered for each test will be in the following sequence and form.

Run Number (3D) = ΦΦΦ
Target Cond (IL) = Φ
PWR. Density (4D) = ΦΦΦΦ
Target Orient. (3D 2D) = ΦΦΦΦΦ
Target Designation (8D) = ΦΦΦΦΦΦΦΦ
Recvr. Cali. (4D) = ΦΦΦΦ
Frequency (MHz) (4D) = ΦΦΦΦ
Modulation (4D) = ΦΦΦΦ
Polarization (H,V) (IL) = Φ
Date (3D) = ΦΦΦ
Ext. Excitation (IL) = Φ

The interpretation of each of these entries will be discussed in turn:

1. Run Number (3D)

The run number for the tests performed will be sequentially numbered, whether the run is on small or large targets. The three digit allocation allows for successive numbering from 1-999. After test 999, the sequence will be repeated. Thus, over the duration of the total test period, several identical test numbers will occur; however these identical test numbers will be separated by significant time intervals.

2. Target Cond (Q, A, O), (IL) = Φ

This entry requires one letter input, Q, A, or D. Q designates a target quiescent condition. A designates an

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activated target condition i.e., if normally engine powered, with the engine running, but with the target stationary. 0 designates a target operating condition and will signify the target moving at a constant velocity along a straight line which is normal to the boresite Poynting vector of the antennas.

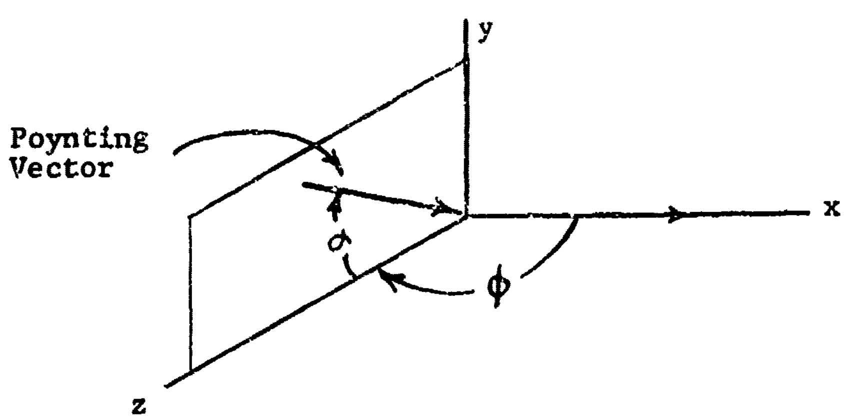
3. PWR. Density (4D) = ΦΦΦΦ

This entry is for the direct wave power density at the target position in watts/m^2. An assumed decimal is between the first and second digits. The third digit is either a + or - sign. The fourth digit is the exponent of 10, the sign of which is given in the third digit place, which multiplies the number given in the first two digits. Thus,

2.3×10^{-2} watts/m^2 is denoted as:

PWR. Density (4D) = 23 -2

4. Target Orient. (3D 2D) = ΦΦΦΦ



Consider the target body as having a body vector associated with it. For the large targets, the body vector can be rotated thru 360° in the x-z plane. It will be rotated in 45° increments. For the test site geometry

chosen, the direct-wave Poynting vector will make an angle of approximately 25° with respect to the x-z plane; i.e. $\alpha = 25°$ if the x-y plane is taken as ground. The angle of rotation will be taken as zero when the target body vector lies along the positive x axis as shown above and the radiation Poynting vector lies in the y-z plane as shown. The Target Orientation entry into the trailer is comprised of five digits.

For large target testing, the first three digits gives the angle Φ and the last two digits gives the angle α between 0 and 90°. If only one test position is used, this angle will be 25°. Therefore, for a large target where, for example, $\Phi = 90°$, the target orientation entry would read:

Target Orient. = 09025

For small target testing, two effective Poynting vector directions will be used , one corresponding to $\alpha = 0$ and the other corresponding to $\alpha = 90$. Thus, the target will be rotated through 45° increments in Φ with $\alpha = 0$, then thru 45° increments in Φ with $\alpha = 90°$. For simplicity in testing of the small targets, the antennas will remain fixed, but the coordinate system will be rotated through 90° when testing at $\alpha = 90°$ is desired. Again, the first three digits of the target orientation designator will define the angle of Φ and the last two digits will define the angle α .

5. <u>Target Designation (8D) = ΦΦΦΦΦΦΦΦ</u>

The first digit of the target designation will always be L for large targets and S for small targets. The remaining digits will be a significant portion of the target serial number or other chosen identifying number.

6. <u>Recvr. Calib. (4D) = ΦΦΦΦ</u>

The receiver calibration factor is a number K which relates the voltage sampled by the A-D converter to the square root of the nonlinear scattering cross section i.e.

$$\sqrt{\sigma} = KE$$

The K factor is taken from the graph of K versus IF knob setting for the appropriate receiving frequency.

For the designation, an assumed decimal is between the first and second digits of the three-digit K factor. The last digit denotes a negative exponent of 10 which multiplies the first three digits. Thus, if the calibration coefficient K is 6.32×10^{-9}, the trailer input would be:

Recvr. Calib. (4D) = 6329

7. <u>Frequency (MHz) (4D) = ΦΦΦΦ</u>

This entry is the fundamental frequency in MHz. Therefore, for a fundamental of 411 MHz, the trailer entry would be:

Frequency (MHz) (4D) = 0411

8. <u>Modulation (4D) = ΦΦΦΦ</u>

The first two digits of this entry will designate the pulse width and the last two digits will designate the pulse repetition frequency. For the pulse width designation, the input will be in microseconds, with an assumed decimal between the first and second digits. Thus, the pulse width can be stipulated to the nearest 100 ns. The repetition frequency designation (the last two digits) will be in kilohertz. Thus, if a 1 microsecond pulse width at a 15 kHz repetition rate is used, the trailer entry will be:

Modulation (4D) = 1015

9. <u>Polarization (H,V) (IL) = Φ</u>

This entry is a single letter designation of the antenna polarization used, with H indicating Horizontal and V indicating Vertical.

10. <u>Date (3D) = ΦΦΦ</u>

This entry will designate the day of the year in which the date was obtained.

11. <u>Ext. Excitation (IL) = Φ</u>

This entry is for indicating the nature of any intentional external stimulation of the target. For most tests, there will be no external excitation and the entry will be N, for None. For tests in which an acoustic sound pressure excitation is applied to the target, the designation will be A.

12. Any other information which is felt may be significant in interpretating the data, and which is not included in the basic trailer data, will be entered on the tape by using the free text mode of information entry.